A Computer Program in QuickBASIC for the Heuristic Design of Looped Water Distribution Networks

User Instructions for
LOOP Version 4.0

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PREFACE

This document is a part of a package of three microcomputer programs and user instructions prepared by Asia Water Supply and Sanitation Sector Development Team (SDT) for computer-aided planning and design of low-cost water supply and wastewater disposal systems in developing countries. It is concerned with the program LOOP Version 4.0 (contained on diskette #2) which uses Newton-Raphson technique and the Hazen-Williams or Darcy-Weisbach flow equations for the heuristic design of looped distribution networks. Version 4.0 handles up to 1000 pipes and 750 nodes as well as multiple sources with fixed or variable heads, fixed or unknown flows, booster pumps, check valves and pressure regulating valves. This program also shows hydraulic gradelines along chosen sections and calculates headlosses, velocities, valve operation status, pumping heads, etc. and costs. The program has been designed for easy entry, storing, editing, and updating of data. It is provided in compiled QuickBASIC form to speed program execution.

The program is not copy protected. However, the program should not be copied for sale or for use by non-recipient without the prior written consent of the UNDP / World Bank Regional Project RAS/86/160.

While developing the current version, due consideration was given to the various comments received from the users on the LOOP program released in December, 1985 by the UNDP Interregional Project INT/81/047 in a package of microcomputer programs; and the present version is expected to better meet the user requirements. However, as the operation of a software is constrained by the hardware in use, all attempts have been made to develop a software which is powerful, as well as compatible with the hardware in use in the developing countries, in general.

The programs are intended solely for use by experienced planners and design engineers; they presume that the user is familiar with such specialized topics as hydraulics, mathematical optimization techniques, etc. The user instructions are limited to information about the use of the programs, and also contains a brief technical note on design principles and equations. However, they are not intended to inform the inexperienced user on, for example, how to layout a pipe network. User instructions . include references to the source material.

SDT extends thanks to one and all whose comments encouraged it to launch another effort to bring out a software which would meet most of the user's requirements. The lead, in this regard, given by the SDT field office in India is highly appreciated.

SDT is interested in receiving information on the performance of these programs in the field and suggestions for their improvement. This information will form the basis for future modifications of the programs. All communications, in this regard, should be addressed to the Infrastructure Division, Asia-Technical Department, The World Bank, 1818 H. Street N.W., Washington, D.C., 20433, U.S.A

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PART-I

1.0 Introduction

LOOP Version 4.0 is an entirely new version of the earlier program LOOP Version 3.0 (written in IBM BASIC) developed and distributed under the joint efforts of UNDP/World Bank. Apart from LOOP, UNDP/World Bank distributed another program called FLOW (written in Microsoft FORTRAN 4.0). FLOW has more features and capabilities than LOOP (Version 3.0) but is far less user friendly for regular use. LOOP Version 4.0, in addition to other technical details, has exploited part of the code of FLOW an4 at the same time enhanced the user interface to result into a more powerful and effective program.

LOOP (Version 4.0), herein referred to as LOOP, could be used for the design and simulation of new, partially or fully existing gravity as well as pumped water distribution systems. It allows for reservoirs (fixed head or variable head viz. pumps), valves (pressure reducing or check valves) and on-line booster pumps. LOOP has been programmed in Microsoft QuickBASIC. Highlights of the improvements made in LOOP are given below.

1. LOOP (Version 3.0) handles networks up to 500 pipes and 400 nodes whereas the LOOP is capable of designing networks up to 1000 pipes and 750 nodes. This is expected to help in achieving a direct one step design of the water distribution networks for even large size towns as against the present situation requiring fragmentation.

2. LOOP (Version 3.0) does only an analysis or simulation of specified water distribution network. The user has to provide the pipe diameters and the program computes flows in pipes, pressures at nodes and the pipe costs. For a medium to large size water distribution network, it becomes very difficult for the user to identify the best combination of pipe sizes, which meets all the desired constraints and yet correspond to a reasonably low cost. The procedure generally followed is then of typical trial and error requiring a number of runs of the program.

LOOP automatically sizes the pipe diameters and thus relieves the user from the burden of making a correct choice. The strategy to size diameters is heuristic and can be effectively controlled by the user based on preferences and judgment. The strategy has been found to yield almost optimal or near optimal network designs. A comparison between the designs obtained using such a strategy and the designs obtained using gradient search technique has shown quite favorable results.

In addition to the automatic pipe sizing option, LOOP allows the user to directly specify the choice of pipe diameters. In this feature, the user is able to force the pipe to follow a certain diameter rather than leaving it to the pipe sizing algorithm used in LOOP. Similarly, the user can specify where parallel pipes are to be provided, and LOOP sizes these pipes so as to meet the required node pressures.

3. LOOP (Version 3.0) uses only Hazen-William's formula as a hydraulic model. LOOP allows for Darcy Weisbach expression as well.

4. LOOP (Version 3.0) uses the Hardy-Cross method of analysis to balance the flows and pressures in the distribution system. This method works well for relatively small networks but it is not recommended for medium to large networks since it is computationally rather slow and does not guarantee convergence. LOOP uses the Newton-Raphson method of balancing which is computationally much faster and has better convergence properties.

5. LOOP (Version 3.0) considers only fixed head reservoirs and not variable head reservoirs such as pumps. Further, it did not have provision to allow elements such as pressure reducing valves, check valves and on-line booster pumps. LOOP considers inclusion of all these aspects in the water distribution system.

6. LOOP (Version 3.0) does not mark the existing pipes in the system explicitly while displaying results of hydraulic and cost calculations. User of LOOP can specify the status of the pipe (i.e. whether existing or new). Accordingly, costs are computed and pipe status is flagged in the outputs.

7. LOOP (Version 3.0) does not have any provision to specify minimum and maximum pressures at nodes. In LOOP, the user has a flexibility to choose node specific values of maximum and minimum pressures. This flexibility becomes necessary to play around in identification of the economic design since the user may wish to relax pressure constraints at nodes and stipulate higher pressures for industrial or fire prone regions. If none are specified, then the program follows the general minimum and maximum pressure criteria applicable to network. Appropriate indication is given in the output to draw attention of the user to the nodes where the specified pressure constraints are not met.

8. LOOP (Version 3.0) does not have a provision to declare different materials of commercial pipe diameters while analyzing the distribution network. LOOP allows the user to specify pipes belonging to a maximum of three different pipe materials and uses this information while analyzing and sizing the distribution system. This addition is expected to orient the computer based modeling closer to real world water distribution system.

9. LOOP (Version 3.0) does not have flexibility to specify input data in different units. Users of LOOP are however allowed to specify pipe length, pipe diameter, flow, elevations, velocity, pressure and head in two types of units (MKS or FPS) and in various combinations i.e. for example, velocity could be in feet/sec and pipe diameter in mm.

10. LOOP (Version 3.0) does not have any provision to allow display of Hydraulic Grade Lines (HGLs) on screen. LOOP has this capability and provides the user an option to prepare longitudinal profile of HGL for specified number of pipes both on screen as well as on a dot matrix printer.

11. LOOP has several additional features to increase its user friendliness and productivity significantly more than LOOP (Version 3.0). These improvements include,

- Window based menus with highlighted bar movement;
- Hierarchical menus;
- Context specific on-line help;
- More useful options in the data editor environment such as,

Basic mathematical operations
Search at all columns
Make column totals
Mark existing pipes and parallel pipes
Key to allow changes in number of pipes and nodes
Key to display features of function keys

Facility to enter head-discharge data as applicable for pumps directly into the program (LOOP has an in-built regression routine to make necessary polynomial equations);

Improved and generalized file operations for copying, renaming/ moving, erasing and saving files;

Other completely new features include,

More sophisticated check data option for finding data entry and syntax errors
Configuration option to allow the user to maintain data files in various sub directories, declare name of organization, name of currency etc.

Automatic check for the equipment configuration and required *DOS* version.

Command line option to set up LOOP for different run time memory models, printer paper specifications, help options etc.

Facility of an on-line electronic abridged user manual

Support to color monitors

Installation routine

While these improvements have been made in LOOP, its data entry environment (e.g. tabular screens) has been maintained very similar to that of LOOP Version 3.0. The features like insert / delete / copy etc. have been retained so as to give the users the same feeling of familiarity. The users of LOOP Version 3.0 are hence expected to adjust very well with LOOP.

2.0 General Data Requirements

The data required to run LOOP can be divided into four classes as follows,

Geometric data

- Node-pipe connectivity
- Length of all pipes
- Ground levels of all nodes
- Location of booster pumps and valves

Hydraulic data

- Average water demands at all the relevant nodes.
- Pipe resistance coefficient in terms of Hazen William's C or pipe roughness co-efficient k in Darcy-Weisbach expression

Source data

- Elevations of all reservoirs
- Data on head-discharge curves for variable head reservoirs

Cost Estimation Parameters

- Available commercial diameters up to three material classes, with data on unit cost and working pressure

- Newton-Raphson stopping criterion (viz. Maximum allowable error in flow balance)

- Maximum and minimum pressure at nodes

- Design hydraulic gradient

3.0 Hardware Requirements

LOOP runs on all IBM-PCs or compatible machines such as PC (with two floppy drives of 360 KB capacity), PC/XTs, PC/ATs, PC-386, PC-486 operating under MS DOS versions 3.1 or above. Minimum RAM requirement is 640 KB for the execution of the program to handle 1000 pipes. (For pipes less than or equal to 500, a minimum RAM of 512 KB is required). LOOP may not be able to handle 1000 pipes if any RAM resident programs are kept active.

Use of a PC/AT is recommended. Presence of a math co-processor greatly helps in reducing the computation time as the program does a significant amount of numeric calculations and is thus strongly recommended.

LOOP runs only on computers with monitors having adapters such as Color Graphics Adapter (CGA), Enhanced Graphics Adapter (EGA) and Video Graphics

Adapter (VGA). The program does not work, on a monitor with Monochrome Graphics Adapter (MGA) and Hercules Graphics Adapter (HGA).

LOOP produces outputs on the disk and on dot matrix printer. The user can further read the output file into any word processor and control the style, character size, format etc. appropriate to his printer.

4.0 Installation Procedure

The contents of the floppy of LOOP for installation are as follows,

File Name	***Description***
INSTALL.BAT	This is the file for installation
LOOP41.EXE	This is the part of the compressed file for LOOP
LOOP42.EXE	This is the part of the compressed file for LOOP

Before installation of the program, make a copy of the program disk as a back-up. Use the DISKCOPY command available in the DOS for this purpose. Put write-protect tab on the master floppy disk as a precaution.

4.1 Installation on PC with Twin Floppy Drive

Before you run installation for twin floppy disk set up, make sure that you have two 360 KB formatted blank floppy disks. The installation program, in fact "explodes" the program from the compressed files LOOP41.EXE and LOOP42.EXE into two 360 KB floppies.

Now boot the PC with DOS diskette in drive A:. Remove the DOS floppy and place the Program Disk into drive A:. Type at the A: prompt

INSTALL f <ENTER>

The installation program now runs step by step. Follow the installation instructions carefully. On completion of proper installation, you should have two 360 KB floppy disks containing the "exploded" LOOP program files.

Contents of Program Disk-1 shall be,

File Name	Description
LOOP.EXE	This is the executable version of LOOP

Contents of Program Disk-2 shall be,

File Name	Description
LOOP4.BAT	This is a batch file to start LOOP
DEMO.LOP	This is the data file for demonstration
LOOP.HLP	This is the help file

4.2 Hard'Disk Installation for **IBM-PC/XT** *or AT*

Boot the machine and place the Program Disk in drive A. Now type at the C: prompt (or D:/E: i.e. whichever hard disk drive in which you want LOOP to be installed).

A:INSTALL h <ENTER>

The installation program now runs step by step. Follow the installation instructions carefully. On completion of proper installation, you should have the "exploded" LOOP program files in the directory LOOP on the hard disk. The contents of LOOP directory are as follows,

File Name	**Description**
LOOP4.BAT	This is a batch file to start LOOP
LOOP.EXE	This is the executable version of LOOP
LOOP.HLP	This is the help file
DEMO.LOP	This is the data file for demonstration
PRTLOP	A utility file

4.3 *Use of the Program*

1. For proper functioning of LOOP, it is recommended that the contents of the CONFIG.SYS file should contain the following commands,

```
FILES=10
BUFFERS=30
```

LOOP'S graphics will not work well if DEVICE=ANSI.SYS is specified in the CONFIG.SYS file.

2. For printing of outputs and graphs, you need to install printer with graphics characters loaded in its memory.

To do so, for hard disk installation, set the path to your *DOS* directory by declaring so in the AUTOEXEC.BAT file *by*: including following command line,

SET PATH = C: \ DOS

where DOS is the directory containing DOS files. Ensure that files such as PRINT.COM, GRAPHICS.COM, GRAFTABL.COM are present in the DOS directory.

In the case of two floppy drive system, insert the DOS system disk containing files such as PRINT.COM, GRAPHICS.COM and GRAFTABL.COM in drive A: and then type the following commands at DOS prompt,

PRINT <ENTER>
GRAPHICS <ENTER>
GRAFTABL <ENTER>

.

In case, all these files are not present in the bootable DOS floppy, you have to place the second DOS floppy into drive A: before typing some of the above commands.

3. For correct printing of outputs, ensure that the DIP (Dual In-line Package) switches of your printer are set either to the option of IBM Graphics or Graphic Characters. You mus t also select the switches correctly to specify the default page length of the paper. Consult the section of Setting DIP Switches in your printer user guide to understand the location of DIP switches and procedure to set them for different options.

For EPSON LX-800 printer and 11" size printer paper, the recommended DIP switches are,

Switch	Function	Status
SW1-1	Type style	Normal DOWN (OFF)
SW1-2	Shape of Zero	Slashed UP (ON)
SW1-3	Character Table Paper	Graphics UP (ON)
SW1-4	Paper out of Detection	Active DOWN (OFF)
SW2-1	Page Length	11 Inches DOWN (OFF) Normal Mode DOWN
SW2-2	Cut-sheet Feeder	(OFF) OFF DOWN (OFF)
SW2-3	Skip-over Perforation	Line feed must be added to Carriage Return
SW2-4	Automatic Line Feed	DOWN (OFF)
		e.g. USA UP (ON)
SW1-6	Country	
SW-7		
SW1-8		

4.3 Setting up **LOOP** *using Command Line Options*

LOOP allows certain run time set-up parameters at its command line to add to the flexibility of its use. These parameters can be set each time you run LOOP or this task can be more easily done by designing appropriate batch file (as per user choice), such as L00P4.BAT.

Contents of LOOP4.BAT file, which is provided along with LOOP program, are as follows,

```
CLS
LOOP /1 /fl /r66 /t3 /b3 /u /cRs /hY /iY
```

The explanation to the various command line options used is as follows,

Options not available directly from configuration

/ 1 or / m or /s : This is an important set up option for run time memory utilization of LOOP. The implications are,

/1 (|arge model) 1000 Pipes, 750 Nodes
Reservoirs (fixed and variable) 20
Booster pumps 20
PRVs20
Check valves 20
Maximum Commercial Diameters 30

/m (medium model) 500 Pipes, 400 Nodes
Reservoirs (fixed and variable) 20
Booster pumps 40
PRVs 40
Check valves 40
Maximum Commercial Diameters 30

/s (small model) 100 Pipes, 75 Nodes
Reservoirs (fixed and variable) 10
Booster pumps 20
PRVs 20
Check valves 20
Maximum Commercial Diameters 20

If you set up LOOP according to the size of the problem you wish to solve, then the available memory is most optimally used. For instance, if you are operating with /s or /m option, you can manage running LOOP in the RAM of 512 KB or keep a memory resident program such as active in the background.

/ f n — n is the number of logical fixed disk drives present in the system. The default is one. For example, if-you have two separate 20 MB hard disks say C: and D:, then you must specify set up option as /f 2. If you have one hard disk of higher capacity and have partitioned the same into three logical drives say C:, D: and E:, then the correct set up option is /f 3. Do not specify higher number of logical fixed drives than the actual number of drives present.

/ r n — n is the total page length in lines (normally 72 for 12" page and 66 for 11" page). Default is 66 corresponding to 11" paper length. (While invoking this option you must have a compatible DIP switch setting of the printer as earlier described)

/ t n — n is the number of lines to be left as top margin. Default is 3.

/ b n — n is the number of lines to be left as bottom margin. Default is 3.

The page layout in LOOP is as follows,

3 lines of Header (Fixed)
Top Margin (User Specified)
Bottom Margin (User Specified)
3 lines of Footer (Fixed)

/u op /a — /a denotes auto-numbering of pipe and node numbers during data entry/editing, /u disables auto-numbering, /u is the default.

/iN or iY — During execution, LOOP prompts intermediate messages such as the band width, number of iterations, unbalanced head/flow, run-time status of PRVs/CVs etc. / iY option is the default. If these prompts are not desired then the user can specify in the command line /iN.

/o — This is a special switch to instruct LOOP to prepare outputs (both in display as well as in printout) based on following sort conditions,

Nodes in the ascending order of residual pressures and pipes in the descending order of the head loss gradient.

Outputs sorted in this form are desirable to focus quickly to the low pressure nodes as well as high head loss pipes in the network for suitable rectification.

The default condition will provide output for the pipes and nodes in the order they are entered.

Options available otherwise from configuration but can be actuated from command line:

/p LPT1 or LPT2	Printer port. Default option is LPT1.
/c	Currency Symbol. For example /c $ initiates the currency symbol as $.
/ hy or / hn	Sound during on-line help, y denotes yes and n as no. Default condition stands for 'yes'. If not stated in the command line, options specified in CONFIG.DAT (explained in the next section) are used.

There is no restriction on the sequence of command line options and you can use both upper and lower letters. There should not be however any space left between / and the option (e.g. / 1 is invalid whereas /1 is a valid command line option).

5.0 LOOP *Session*

In this section we will make you familiar with the use of the LOOP using an example DEMO.LOP data file. By the end of this session you should have working knowledge of all the options and menus of LOOP. Here we will use the following syntax for explaining the use of LOOP.

1. The Capital letters (e.g. LOOP4) means that you should type the text in a similar way, either in lower or upper case, as specified in the manual.

2. The text when specified in the brackets (e.g. <ENTER>) corresponds to the key on the keyboard which you are expected to press.

3. The text such as C:\LOOP> is the DOS prompt on your monitor (D:\ LOOP> \ if you installed LOOP on drive D:). If you have a different DOS prompt, you can change to similar prompt by adding a line PROMPT = SPSG in the AUTOEXEC.BAT file. (Consult your DOS Manual if required).

4. The text in italics (e.g. User Manual) corresponds to an option in the menu.

To run LOOP now from the Hard Disk, boot the PC and change to the drive where LOOP sub-directory is present and then change to sub-directory LOOP by typing the following text at the root directory of your computer.

CD \ LOOP <ENTER>

Now type,

LOOP4 <ENTER>

to invoke LOOP with default command line options listed above.

To run LOOP from twin floppy PC, boot the PC and activate the PRINT, GRAPHICS and GRAFTABL files as explained earlier. Place program disk-1 in drive A: and in drive B: the program disk-2. Change to drive B: and at the DOS prompt type

LOOP4 <ENTER>

to invoke LOOP with default command line options listed above.

5.1 Configuration Screen

Now, LOOP will be loaded into the memory, and the opening flag of the program will be shown. Press any key and a message will appear on screen, saying that the CONFIG.DAT file not found in the current directory. Press any key other than <ESC> and you are shown a Configuration Screen (refer to Figure 1). In configuration screen, you can specify the drive and directory (i.e. path) of the program, data and output files.

For floppy drive installation, type the drive specifications in the configuration screen, corresponding to each prompt, as follows,

Program Directory <A: \ >: A:
Data Directory <A: \ >: B:
Output Directory <A: \ > : B:

For hard disk installation, the configuration screen, will show the directory path C:\LOOP\ (assuming LOOP was installed in C:\LOOP directory) corresponding to each prompt, as follows,

Program Directory <C:\LOOP\> :
Data Directory <C:\LOOP\> :
Output Directory <C:\LOOP\> :

Leave the above three entries as blank so as to consider the default path (i.e. C:\ LOOP \ ).

Main Menu

User Manual

LOOP Version 4.0 <<Configure Secreen>> Version 4.0 LOOP

Program Directory <c:\LOOP/>:

Data Directory <C:\LOOP\DATA\>:

Printer Port <LPT1> :

Help Sound Required <Y>:

Currency Symbol <Rs>:

Organization Name <World Bank UNDP>:

Save Changes (Y-Yes OR N-No) <N>:

Press <ESC> to End

Use to choose
Change present Setup

CONFIGURATION SCREEN FIGURE 1

Here, if you attempt to specify a non-existent directory or drive, then an error message is flashed as "Path Not Found, Re-enter Proper Drive and/or Sub-directory".

In addition to above, you can also specify the name of the organization up to 20 characters (which appears at the bottom row of the screen) and currency symbol (which appears against all cost related items). At the currency symbol, you can enter signs such as $ and emulate symbol for Sterling Pounds by key combination of <ALT> and 156 (i.e. keys 1, *5* and 6 from the numeric keypad). To enter symbols other then $ or £, you have to emulate the sign using key combination of <ALT> and number (refer to ASCII table for specific number) as typed from numeric keypad. This facility is however available only from the command line option viz. /c. You can set up your printer by specifying printer port either as <LPT1> or <LPT2>.

During the data entry environment, function key [Fl] is made available for popping on-line help. The helpful text in a window can appear character by character with sound or can be dumped on the screen without it. Normally, first time users of LOOP may like the help to appear character by character so as to assimilate the helpful information in a better manner. On regular use of LOOP however, the user may not like to be in such a learning mode. You may therefore type either "Y" or "N" at the option of Sound on On-Line Help? depending on your experience with LOOP.

Press <ESC> to save and exit the configuration options. At this step, a new file called CONFIG.DAT is created in the program directory, which stores the configuration information. In all future runs of LOOP, the present configuration is assumed (until you make further changes) and hence the message "CONFIG.DAT file not found" does not appear again. Now you will be once again shown the opening flag of the program and on pressing any key, the first screen of LOOP appears, showing the Main Menu.

You must have observed that the option of currency, printer port and help sound in configuration are also included as options in the command line setting of LOOP. It must be noted however that for a particular run, command line options will always override the options specified in the CONFIG.DAT file and hence you can set the run time options for setting LOOP without actually changing the CONFIG.DAT file.

5.2 Main Menu

The topmost line in the first screen will always display LOOP Version 4.0 on the left side, and current date (which is obtained from the system) on right side. The date may need resetting if the system does not have a battery backup facility for maintaining the internal clock. The bottom most line will display the name of the organization, copyright and current path of data file (and name of data file if opened).

On the left-center portion of the screen is the Main Menu of LOOP (refer to Figure 2). This Main Menu shows options such as *User Manual, File Operations, Solve Network, Print Files, Configure and Quit.*

A pointer in the form of a highlighted or inverse video bar (hereafter referred to as highlighted bar) can be seen on the first item on the menu viz. User *Manual.* Below the

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Main Menu

User Manual

FILE OPERATION

SOLVE NETWORK

PRINT FILES

CONFIGURE

QUIT

Use to choose

Load/Creat/Edit/Copy/Erase/Rename/Move/Check File

World Bank UNDP **(C) WB/UNDP** **C:\LOOP\DATA**

CONFIGURATION SCREEN FIGURE 2

Main Menu, a footer line is placed which explains how to move the highlighted bar upand down i.e. using the <UP> and <DOWN> arrow keys and choose an option by pressing <ENTER>.

By moving the highlighted bar, up and down on the main menu, you will note that the second last line at the bottom of the screen gives a short description of the item on which the highlighted bar is pointing. This description changes with the highlighted bar position.

At this stage, let us try an example. Move the highlighted bar to the option *User Manual* of Main Menu. Pressing <ENTER> gives you an opportunity to refer to an abridged user manual. You have an access, to the keys such as <UP>, <DOWN>, <PGUP>, <PGDN>, <HOME> and <END)> to browse through the helpful text or alphabet keys from A-N for navigating quickly through selected sections of user manual. On pressing <ESC> key, the Main Menu will be shown once again.

Now let us have a look at the other options on the Main Menu. The option *File Operations* will lead you to another sub menu called File Menu (refer to Figure 3). This sub menu helps you in performing file operations such as *Load/Dir Data, Create/Edit Data, Merge Data, Copy Files, Rename/Move Files, Erase Files, Save Data File, Check Data.* Press <ESC> to return to the Main Menu.

One important point to be kept in mind is that a data file should be either loaded or created (i.e. opened) before choosing the *Solve Network* option or any options under File Menu. As an exercise, try to choose the *Solve Network* option without loading or creating any data file, the program flashes a message warning "Data file Not Opened. Cannot Solve Network".

The option *Solve Network* will simulate/design the water distribution network according to the data supplied and will show results in terms of tabular or graphical form via Display Menu.

The option *Print Files* will lead you to another sub menu called the Print Menu. This sub menu helps you to take a hard copy (i.e. print out) of the input data or output files.

The option *Configure* allows you to re-configure the setup in which the program is presently running. Pressing <ENTER>, the program shows the Configuration Screen, where the set up information can be changed.

The option *Quit* will terminate the program and verify whether you want to save the data file currently created or edited. After your response, you are taken back-to the DOS prompt with closing screen similar to the opening flag.

Main Menu

User Manual

FILE OPERATION

SOLVE NETWORK

PRINT FILES

CONFIGURE

QUIT

File Menu

Load/Dir Data

Create/Edit Data

Merge Data

Copy Files

Rename/Move Files

Erase Files

Save Data File

Check Data

[Esc]-Main Menu or Use to choose

Create/Edit Data File

World Bank UNDP **(C) WB/UNDP** **C:\LOOP\DATA**

FILE MENU FIGURE 3

5.3 File Menu

After getting an idea of all the Main Menu options, we will explore the various options of sub menus and try to learn each option by using the demonstration data file called DEMO.LOP. Figure 4 shows a schematic diagram of this data file.

As a first step, select the *File Operations* option from the Main Menu. From the F: Menu, select the *Load/Dir Data* option and a list of all data files (i.e. having extension .LOP) residing in the specified data directory will be displayed (refer to Figure 5). Do n pile more than 60 data files at one time in the data directory. In this screen, hereafter referred to as File Selection Screen, a long highlighted bar appears and is placed on the name of the first data file. Pressing the <DOWN>, <UP>, <RIGHT> or <LEFT> arrow keys, this highlighted bar can be moved to the name of the data file which is to 1 selected. Then press <ENTER> to load the data file. In this case, only one data file (vi DEMO.LOP) is present and the highlighted bar is already on this file name. Pre <ENTER> and the DEMO.LOP data file will be loaded.

Now select the *Create/Edit Data* option of the File Menu and you will enter the data entry editor with first data entry screen (General Information (Scr-D) of DEMO file. The description on how to enter/edit data in the data entry screen is given later. Presently exit the editing mode by pressing <ESC> to return to File Menu. Now select *Create/Edit Data* option once again, and a dialogue box will appear prompting you to enter the data file name to be created/edited. If the data file is already loaded (as above) then the currently loaded data file name appears in the box, along with its full path. Sin* DEMO.LOP was last loaded, you will see the string "C:\LOOP\DEMO" in the be assuming C:\LOOP\ is the current data directory. At this stage, if you desire, you *a* specify a new data file name to create a new data file. To do so, press <CTRL> arrow <END> to clear the box and then typing the new data file name. If the new data file name does not exist, then a new file will be created. If you attempt changing the currently data path in the box, then an error message is flagged "Path Cannot be Changed".

You can also view data files selectively in the file selection screen, by specifying DC wild characters * and ? in the file name. For example, type D* or D??????? to view and data files in the current directory starring with alphabet D and having extension of .LOP

At this stage, type a new file called DEMOl in the dialogue box and press <ENTER You will see a flashing message at the left-bottom of the screen "Save DEMO.LOP YES (Y/N)". Press N (or space bar to toggle from YES to NO) and then press <ENTER>. You will be shown the first data entry screen (General Information (Scr-D) the new data file DEMOl .LOP. In order to exit from such an empty data file, you mi fill the fields of number of pipes and nodes. Press <DOWN> arrow key to assign default at these fields and then press <ESC> to return to File Menu.

Now choose the *Load/Dir Data* option and re-load the DEMO file. Before the DEN/ file is loaded a warning message will appear such as,

File DEMOl .LOP already Opened, Attempting to Load Another File DEMOl .LOP

May Not be Saved

LOOP Version 4.0 20 June 1991

C:\LOOP\DATA

DEMO . LOP	**SAMPL1. LOP**	**SAMPL2,LOP**	**WADIS01 .LOP**	**WADIS03 .LOP**
	TEST .LOP			

2390016 BYTES FREE

[Esc]-Main Menu or Use to choose

World Bank UNDP **(C) WB/UNDP** **C:\LOOP\DATA**

FILE SELECTION SCREEN FIGURE 5

Since we are not interested to save DEMO1.LOP file, press any key to load DEMO.LOP. If you want to save the currently opened file, then press <ESC> and save the file before loading another file. A similar message will appear just as a matter of caution. You will be prompted to save the data file whenever an attempt is made to change the currently opened data file, to avoid accidental loss of data.

Now select the *Copy Files* option and a dialogue box will appear prompting to enter the source data file name, which is to be copied. While entering the source file name, you can specify the directory path or another drive if so desired. Extension .LOP is taken as default, but you can specify any other extension as applicable to other types of files. For example, you can do copy operations for output files by specifying .OUT extension.

For viewing files in the current data directory, you can type DOS wild card characters such as * and ?. For example, clear the box (using <CTRL>+<END> keys) and type * (or *.*) to view all the files (not restricted to .LOP) or type *.LOP to view only LOOP data files. You can type D???????.OUT or D*.OUT to view all output files in the current directory starting with alphabet D and having extension as .OUT. You will be shown the file selection screen (similar to *Load / Dir Data* option) for viewing the files and having facility of the long highlighted bar with cursor movement to select a particular file you want to make a copy. You can even place the bar on directory name to navigate through the directories in the specified drive.

If a data file is already loaded then its name along with full path will appear in the dialogue box. Enter the desired file name and path as applicable, and press <ENTER>. If this file does not exist then an error message will flash as "File/Path Not Found". If this file exists then another dialogue box will appear prompting you to enter the target file name. Enter the target file name and press <ENTER>. The source file will be copied to the target file. If the target file already exists then you are prompted whether to replace the previous data file or not. If your response is yes (Y) then the file copy operation takes place. Presently, the file name, DEMO should appear as a source file name. Press <ENTER> and then type DEMO1 as the target file name. Press <ENTER> and a copy of DEMO.LOP will be made into DEMOl.LOP file.

Now, there is a word of caution. For the copying operation itself, LOOP requires at least 3 to 4 KB of extra memory space. When you load LOOP with limited effective RAM (e.g. 512 KB) and a medium or large network, adequate memory may not be available for the purpose of copying large data files and the program may crash with overflow error message. In such situations, use direct DOS operations for copying of files.

Select *Rename/Move File* option, a similar type of dialogue box will appear, as in the copy option, but it will be empty. This option changes the specified (source) file name to the target file name. Presently, type DEMO1 as a source file name and DEMO'2 as a target file name. The DEMOl.LOP file will now be renamed as DEMO2.LOP file. Alf the general file access facilities described in copy operations are available here.

On selecting the *Erase* option, an empty dialogue box will appear prompting you to enter the file name, which is to be erased. Type DEMO2 as the file to be erased and press <ENTER>. You-are now asked about the confirmation by a flashing message

Erase File DEMO2.LOP
NO
Are You Sure (Y/N) ?

Type Y or press space bar and then <ENTER> to confirm erasing of the DEMO2.LOP file. File DEMO2.LOP is now erased or deleted from the disk. You should use this option cautiously, as once a file is erased, it will not be restored again. But at the same time if your data directory contains too many data or output files, it may be advisable to use this option on unwanted files. All the general file access facilities described in copy operations are available here.

The options under File Menu like *Copy, Rename/Move* and *Erase*, are very useful since they allow you to perform copy, rename and erase operations on data as well as output files without exiting LOOP and going to the DOS prompt. You cannot however alter (copy into, rename/move or erase) the currently loaded data file. You can try. renaming or erasing DEMO.LOP data file as an example and you will see an appropriate error message.

On selecting the *Save* option, you will be shown a dialogue box with the name of the currently loaded file with its path. At this stage, you can change the file name as well as the directory path or drive by typing the same in the dialogue box. Press <ENTER> to accept the file name as DEMO. Since file DEMO.LOP already exists, you will be shown a confirmation screen with a message "File Already Present, Want to Overwrite? YES (Y/N)". Type N or space bar and press <ENTER> not to overwrite the file.

On selecting the *Check Data* option, the currently loaded data file will be checked for data entry mistakes. Data checking is a simple way to identify the obvious mistakes such as typing errors, and thus avoiding the chances of "crashing" while solving the network. To get a feel of check data option, go to the option *Create/Edit Data*, and press <ENTER> twice to enter editing mode (now to edit DEMO.LOP file). You will see the first data entry screen - General Information (Scr-I). Press <TAB> key to scroll into the second data entry screen. The cursor will be positioned at pipe number 1 under the heading of "Pipe No.". Remove the pipe number "1" using <DEL> and then press <ESC> for exiting data editing mode. Now, select *Check Data* option. A flashing error message appears, "Pipe Number Should Not be Zero. Check Position 1 in Pipe Screen". This is an example how the check data routine helps you in identification of the type of error and also the probable place of error.

Press any key and then re-load the DEMO.LOP file using *Load/Dir Data* option. Select *Check Data* option and now a message appears that "No Possible Data Entry or Syntax Errors Found" (since you did not save the edited version of DEMO.LOP file and the original error free DEMO.LOP file was reloaded, no error was detected).

In order to protect execution of LOOP from "foul" data files, it is a good practice to run check data routine during the process of designing. The advantage of keeping check data as a separate option is however to let the user have a quicker access to re-edit the data file.

In addition to the above options, there is also an option for *Merge Data.* This is an option where you can cojnbine two LOOP data files to prepare a single file. The following are however the restrictions in the use of this option.

- the files to be merged must be created by LOOP
- merging implies that the first file specified is the mother file and the second file is appended.
- in the merging process only the pipe data and node data is appended. The number of pipes and nodes automatically increases in the first data entry screen.
- in the merging process, only pipe and node data from second data file is merged and not the data on fixtures such as reservoirs, booster pumps and valves.

5.4 *Simulate and Display Results*

After exploring all the possible options in the File Menu, let us move to the solve *Network* option of the Main Menu. LOOP could be run either in the Simulation mode (S) or Design mode (D); S and D options are to be specified in the data file. (You will learn more about this in Part II of the Manual). Presently DEMO has been set up for the purpose of Simulation. Select *Solve Network* option and the program carries out simulation of the network.

During simulation, LOOP displays first message such as "Do You Want to Check Data Before Proceeding? YES (Y/N)" with another box pointing that data related to Pipe, Node and other Misc. items have not been checked. Press <ENTER> to check data, and you will see messages such as Checking Pipe Data, Checking Node Data and Checking Misc. Data followed by flashing message as "Calculating.. ". At this point the network solution algorithm starts functioning.

Now at the bottom of the screen a window with caption as "Simulation Messages" appears. Here a number of intermediate messages are displayed such as Newton-Raphson iterations, Bandwidth, Number of loops. Valve settings if any, Balancing head and Flow errors if any, warning messages as applicable etc. (Refer to Figure 6). Consult Part III for the technical information on some of these terms. In some cases, a beep comes and you will be prompted to press any key to move further. After all calculations-nre over, a message such as "Done .." appears and the Display Menu (refer to Figure .7) will appear on the screen.

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Main Menu

User Manual

FILE OPERATION

C a l c u l a t i n g . . .

CONFIGURE

QUIT

Simulation Message

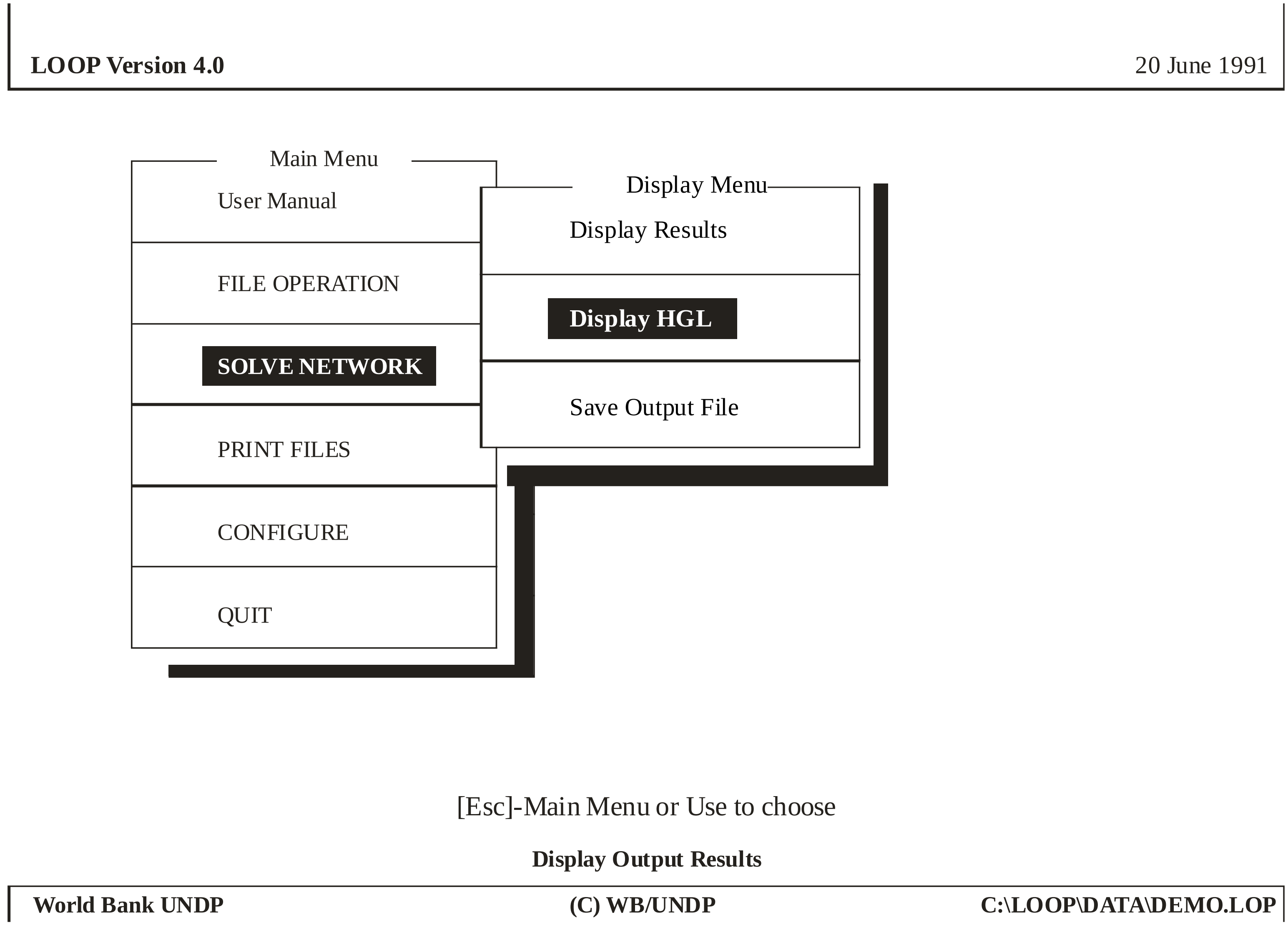
Newton Raphson Iteration = 6

PRV in Pipe # 23 is Not Operational at Iter # e

Done . . . Press Any Key

Design or Simulate Looped Water Distribution Network

World Bank UNDP **(C) WB/UNDP** **C:\LOOP\DATA**



DISPLAY MENU FIGURE 7

Now let us explore the Display Menu. Here, options such as *Display Results, Display HGL, Save Output File* are available.

On selecting *Display Results* option, another sub-menu called Result Menu appear (refer to Figure 8) having options such as *Pipe Details, Node Details, Pipe Cost, Reservoir, Booster Pump, PRV/CV.* Choose each of these options and familiarize with the various items displayed on the screen. Wherever the information is not applicable for options such as VH Reservoir and PRV/CV in the DEMO file), no output is shown

On selecting *Pipe Details* option, the details such as pipe number, its corresponding "From" and "To" nodes, peak flow, pipe diameter, headloss, gradient (per 1000 length units), length and velocity are displayed. You can use <PGUP> and <PGDN> key scroll the pages, <UP> and <DOWN> keys to move one line up or down, and <HOMI and <END> keys to reach beginning and end of the current output respectively, key facilities are available for viewing all the options in the Results Menu. Press <TAB> to scroll to next screen, where you are shown pipe number, its corresponding "From", "To" nodes, diameter, friction coefficient (Hazen's C or Darc/s k), pipe material maximum pressure, allowable pressure and pipe status (existing or parallel). If the maximum pipe pressure exceeds the allowable pipe pressure, a flag such as "HI" (i.e High) appears. In such cases, you could take action of installing PRVs or change positions or change pipe class/materials. Press <ESC> to return to Results Menu.

On selecting *Node Details* option, the details such as node number, (peak) nod flow, elevation, HGL and pressure are displayed. All source nodes (fixed head as we as variable head sources) are marked as "S". Results about fixed head reservoirs ail available in this menu itself. Flags such as "HI" and "LO" (i.e. High and Low respectively are tagged wherever nodes do not meet the necessary minimum and maximum pressures.

On selecting *Pipe Cost* option, the summary of cost for the water distribute network in terms of diameter, pipe material, length (total), corresponding to ii cost and cumulative cost are displayed. Press <TAB> and you will see additional such as pipe number, diameter, pipe material, length and cost. These details pertain only to the new pipes to be laid and not to the existing pipes.

If there are variable head reservoirs, then the option of *VH Reservoir* will show the node number, four regression coefficients between Head (H) and Discharge (Q (designated as PO, PI, P2 and P3) internally established by LOOP using H-Q number of pumps, pump height (elevation), flow at each pump and head.

If there are booster pumps, then the option of *Booster Pump* will show the pipe number, four regression coefficients between Head (H) and Discharge (Q) Designated as BO, Bl, B2, and B3) internally established by LOOP using H-Q data, number of pump flow at each pump and head.

If there were any PRV/CVs present in the system, then the option of *PRV/CV* will show information such as "Pipe # containing a CV is operating/not operating" or "PRV in Pipe # is Not Operational/Operational/Acting as CV" etc.

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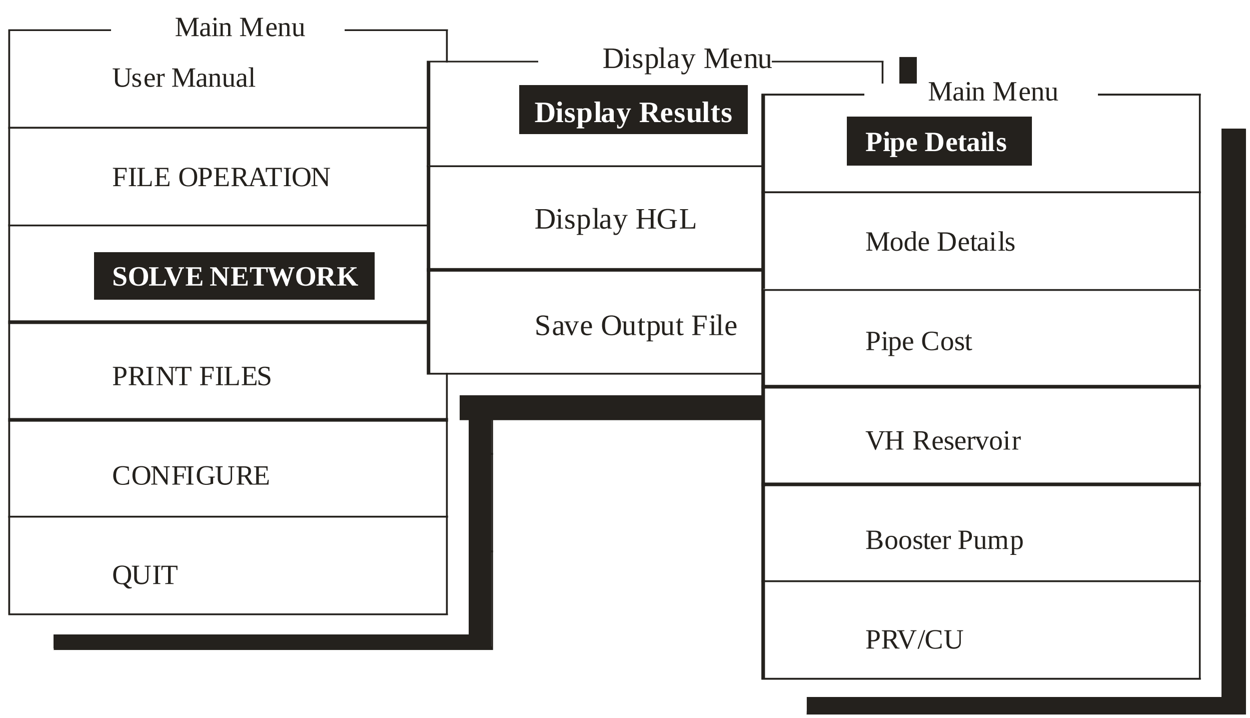

[Esc]-Main Menu or Use to choose

Display Pipe-wise Flow, Diameter, Head Loss, Velocity etc.

World Bank UNDP **(C) WB/UNDP** **C:\LOOP\DATA\DEMO.LOP**

RESULTS MENU FIGURE 8

Select *Display HGL* option from Display Menu and you will be asked to ent sequence of pipe numbers for which HGL is to be viewed. Refer to Figure 9 carefully and enter the pipe sequence as follows,

1,3,4,8,15,14,20,22,

You will now be shown on the screen a profile of HGL and ground level with appropriate node and pipe labeling.

The rules for entering pipe numbers are as follows,

- pipe number must be ending with a , (comma) after the last pipe number entered.

- pipe numbers should exist and the sequence of pipe numbers should represent a continuous path (else an error message is given)

If you want to print the screen on the dot-matrix printer, make sure that printer. is connected and set on with a paper. Press P for taking a printout of the section on the screen. After printing is completed, press <ESC> to return to Display Menu.

On selecting *Save Output File* option, two options are displayed viz. *Without Input* or *With Input.* Saving with input file may be desired for the final runs where you may be interested to record the full details. For the present, choose the option of *Without Input* and a dialogue box appears prompting you to enter the output file name, in which the results will be stored. Presently, file name DEMO would appear with its path. Press <ENTER> and the output results will be saved on the disk in the file called DEMO.OUT.

On selection of *Print Files* option from the Main Menu, a Print Menu is shown with options such as *Input Data* and *Output Result.* Choose the option of *Output Result.* You will have a dialogue box asking you to enter the file name to print. You can directly type the file name as DEMO to instruct the program to print DEMO.OUT file. Additionally, you can also view the files using the DOS wild card characters such as * and ? and select the file to print. Type * and <ENTER> to view all the files with extension .OUT in the output sub-directory. You will see only one file viz. DEMO.OUT. Select the file by focusing the highlighted bar. The dialogue box would now have the file name as DEMO.OUT with path as C:\LOOPV Press <ENTER>.

A message box now appears instructing you to set the printer on. (You could press <ESC> at this stage if you want to abort printing). Set the printer on and then press a key. Now you have another message box asking whether to pause between pages. Press <ENTER>'to accept the default (printing with pause). The results are now printed page by page on the printer and at end of each page you are prompted to press a key.

Now check the results of DEMO.OUT thus printed with the output file print out given in the Appendix - A. These should exactly match.

5.5 *Network Design*

In order to get a feel about the diameter finding capability of LOOP, edit the DEMO.LOP file (via. *Create/Edit Data* of *File Menu)* by following the instructions given below carefully,

Press <TAB> to view the Pipe Data screen (Scr-II). Now place the cursor on the first row on the Diameter column by using <ENTER> key four times.

The cursor should be focused now on diameter of 200. Delete the same using <DEL> key.

Press F5 function key and type 24 at the prompt of "No. of Copies:". Press <ENTER>

You should now see the entire Diameter column blank or devoid of any values.

Press <TAB> five times to reach the screen of Design Information-Scr XIII. Bring the cursor to "Simulate or Design" using the <DOWN> key. Change S to D by over typing.

Press <ESC> twice to return to the Main Menu.

Now we will solve the network under design mode to "find" the diameters in the network such that the specified constraints of pressures are met and the cost of pipes is minimum.

Choose the option of *Solve Network. A* message is flashed "Do You Want to Check Data Before Proceeding? YES (Y/N)" with a message box pointing that data related to Pipe and other Misc. items have not been checked. Note that the message at this stage does not point at checking of Node Data as done in the first case. This is because you did not make any change in items related to the Node Data Screen (Scr-III) and changes were made only at the Pipe Data Screen (Scr-II) and Design Information Screen (Scr-XIII). This is an illustration of the dynamic character of check data routine in LOOP. Press <ENTER> to check data.

You will see messages such as "Checking Pipe Data", "Checking Misc. Data", followed by "Calculating ...". Now at the bottom of the screen a window with caption as "Simulation Messages" appears as described before (refer to Figure 6). Press any key and you will see another box called "Design Messages" showing details such as Iteration Number, Feasible Cost and Initial Cost. Cost corresponds to that of new pipes. Press a. key (or <ESC> to abort) and you will be shown results of iteration #3 (costs of iteration #2 not shown since solution being infeasible). The cost at iteration #3 will be 462.90 (*1000) as compared to 922.20 (*1000) showing a reduction in the cost.

The design algorithm finds the economical diameter combination and displays the pipe cost in the Design Message box only when it is feasible (else the iterations continue till a better feasible solution is struck). Press a key each time to view the design process.

For each iteration in the design process, you will notice a change in the Newton-Raphson iterations required in the Simulation Message Box.

At iteration #11, the feasible cost will be 427.90 (*1000) and a message such as Done " appears at the Simulation Messages box. Press any key to reach the Display Menu. Under the pipe details, you will see the "new" diameters "found" by LOOP. Check these diameters with those inputted earlier and you will notice the following,

1. The cost of the network under automatic design is lower than the one earlier provided (427.9 (*1000) as against 443.40 (*1000) leading to a saving of 3.5%.

2. The pressures at nodes in the automatic design are well within the limits specified.

Now edit the DEMO.LOP file via *Create/Edit Data* option of the File Menu and you will see the diameters found "copied" under the Diameter column of Scr-II. If you save the file at this stage then DEMO.LOP will be saved with these diameters.

At this point, change the Design Hydraulic Gradient in Scr-XIII from 5 to 8 and solve the network. The initial cost displayed under design messages shall be 427.90 (*1000) and not 922.20 (*1000) shown earlier. This is because LOOP uses the diameters found (for Design Gradient of 5) as the initial condition. In this case, the solution will not change since 427.90 (*1000) happens to be the least cost solution.

This is a useful approach especially if you want to explore fine-tuning of the solution by trying different design gradients successively. Alternatively, you may retain diameters of only few selected links and let LOOP choose the remaining diameters for say another design hydraulic gradient.

On the other hand, if you want to redesign the network from scratch for a new hydraulic gradient of 8, you must set the diameters found in the earlier run to zero following the editing procedure described before re-solving the network.

The relationship between design hydraulic gradient and pipe cost is non-linear but generally low hydraulic gradients (e.g. 1) will lead to expensive solution compared to high hydraulic gradient (e.g. 10). Another characteristics is that the solution for high hydraulic gradient is relatively fast but the pipe velocities in few pipes will be on the higher side. Conversely, if very low hydraulic gradient is used, then the solution time is more and in some sections the pipe velocities are lower. One therefore, needs to adopt a procedure of intelligent trial and error to settle on the best solution. The optimum may be generally observed between design gradients of 2 to 5.

This tour of several menus and sub-menus completes our first exploration of LOOP. Return to the main menu, by pressing <ESC> and choose the option *Quit* to exit LOOP.

network. Figure 10 is a schematic diagram of the TEST network showing the location of reservoir and demand nodes as well as locations of three pressure reducing valves. In addition to this diagram, a print out of the input data has been enclosed in Appendix-B to ease your data entry. This example has been adopted from Walski et al [13].

6.2 *Numbering Technique*

Now let us assign a number to each pipe and each node. The numbering should be done for pipes and for nodes separately, usually starting from number one. Care should be taken not to repeat the same number within the set of nodes or within the set of pipes. The numbers assigned for the nodes and pipes in TEST network are shown in the diagram (refer to Figure 10).

6.3 *Resetting Configuration*

Now that you are creating a new data file, it is recommended that you create a new sub-directory for better housekeeping of data files. In the case of hard disk use, make a sub-directory DATA by typing at C:\LOOP> (assuming LOOP is installed in drive C:) prompt,

MD DATA <ENTER>

Now, load LOOP by typing,

LOOP4 <ENTER>

Choose the *Configure* option from the Main Menu and modify the options suitably. Some of the important changes you could introduce at this stage are,

1. Directories: Declaring the newly created sub-directory LOOP/DATA as default for input and output data files

2. Currency symbol: The default is Rs. But, you could enter abbreviation specific of your country up to 3 characters.

3. Name of the organization: This will appear at the bottom line of the display screen.

Once the Configure Screen is edited, type Y at "Save Changes: (Y/N)" to save the screen and then <ESC> to end. Now the new configuration is written to file (CONFIG.DAT) in the program directory. The new configuration options you indicated shall now be used during future execution, till you reset the configuration once again. If you had chosen N option at "Save Changes", then the new setting is kept operational only till you exit this session of LOOP and the CONFIG.DAT file remains unchanged.

For floppy drive installation, place a new formatted disk in Drive B: to receive data and outputs.

6.4 Data Entry Environment

Now choose the option *of File Operations* from the Main Menu. Select the *Create/Edit Data* option. You will now see a *file* selection screen as in Figure 5 indicating that there *is* no data file in the current directory. Press <ESC> to create data file, and you will have a dialogue box prompting to enter the Data File Name. Enter the data file as TEST and press <ENTER>. The program will take you into data entry editor showing the first data entry screen (viz. General Information Scr-I).

The screen will typically show a top bar with program name and date and a bottom bar indicating name of the organization, sponsor of the software and the name of the current data file with its path.

The data entry screen has excellent data editing facilities made available through preprogrammed function keys. Information on function keys can be seen at the bottom portion of each data entry screen. The following table lists the different editing facilities available.

Explanation to the various preprogrammed function keys is as below,

Function Keys

[Fl] Provides a pop up screen having context specific help. If sound is chosen in the configuration option, then the help text is flashed on the window with an emulated sound of a typewriter.

[SHIFT] + [Fl] Displays a text showing a summary of features of both ordinary keys as well as function keys reserved for editing facilities

[F2] Inserts a line at the cursor position.

[F3] Deletes a line at cursor position.

[F4] Appends (or adds) a line at the bottom of the data entry screen.

[F5] Copies a value down the cursor position in the same column. User is asked to specify the desired number of times copying is to be done.

[F6] Does a mathematical manipulation to the value at the cursor such as,

* (Multiply)
/ (Divide)
\+ (Add) or
\- (Subtract)

To make use of F6 key, place the cursor under the field of interest. Now press F6 key. At the bottom of the screen a prompt will appear as, Equation?

Choose the scaling factor, e.g. if you are changing original data of length in meters to feet it would need a scaling factor of 3.28. Hence, type at the prompt the following,

3.28 <ENTER>

This will lead .to another prompt on the same row asking number of rows to be modified below the present location of the cursor.

F6 key has thus a potential use for doing mathematical manipulations in the columnar data. Few additional tips must be however remembered while making use of F6 key.

F6 key is available only to selected fields on the screen. For example, it is inactive for operating on fields such as Pipe No., Node No. etc.

F6 cannot-be used to produce unacceptable numbers of questionable signs. To illustrate this situation, consider variable like head (which is always expected to be positive). If the original data is 100 and the user tries to subtract 150 using F6 key, then the result will not be -50 but 50.

Due to restrictions on the significant number of the variables, use of F6 key will eventually lead to some loss of precision in the converted data. This must be borne in mind especially if you attempt comparison between original and modified results.

[F7] Displays the total of all values down the cursor position (including the value at the cursor position). This facility is useful to obtain instant total of fields such as flows, lengths etc.

[F8] This is a special key designated to mark the existing pipes in the Pipe Data (Scr-II) screen.

[SHIFT] + [F8] This is a special key designated to mark the parallel pipes in the Pipe Data (Scr-II) screen.

[F9] Searches the specified value in the column where the cursor is positioned and if the search is successful then shifts the location of the cursor to the matching value.

[F10] This is a special key available only in the General Information (Scr-I) screen. which when pressed allows the user to type over the number of pipes and number of nodes.

It is to be noted that all of the above keys may not be available for each screen or for each and every columns of a particular screen. For example keys such as [F5], [F7] and [F9] are not available in the first and the thirteenth screens (i.e. General Information (Scr-I) and Design information (Scr-XIII) respectively) and keys such as [F5] and [F6] do

not function on Pipe No., From Node and To Node of Pipe Data (Scr-II) screen and Node No. of Node Data (Scr-III) screen.

Other Keys

Key to be Pressed	Facility Offered
<UP>	Move up one line
<DOWN>	Move down one line
<RIGHT>	Move right one character
<LEFT>	Move left one character or to the previous field
<ENTER>	Accept entry and move to the next field
<HOME>	Move to first entry in column
<END>	Move to last entry in column
<PGUP>	Go to previous page of the same screen
<PGDN>	Go to the next page of the same screen
<INS>	Insert a space in between two characters
<DEL>	Delete a character at cursor position
<BKSPACE>	Delete a character before cursor position
<TAB>	Move to next screen
<SHIFT> + <TAB>	Move to previous screen

6.5 General Information (Scr-I)

This screen accepts general information on the water distribution network like number of pipes, number of nodes, number and material of commercial diameter, type of hydraulic formula and units to be used for length, diameter, flow etc. A blinking cursor will be positioned in the first row where you have to enter the Title of the Project. A number of pre-programmed function keys are available for editing. Press [SHIFT] and [Fl] keys to view the capabilities of these keys. After entering the data, corresponding to each field as required, you can move to the next field by pressing the <ENTER> or <DOWN> key.

To enter the data in this screen follow the steps as given below:

1. **Title of the Project**: Type the title of the project for data file identification purpose only (Maximum length allowed is 44 Characters). Both alphabets and numbers are allowed.

   Enter TEST as the title of the project.

2. **Name of the User**: Type the name of user for data file identification purpose only (Maximum length of 19 Characters).

   Here you can enter your name. No numeric keys are allowed.

3. **Number of Pipes**: Enter the total number of pipes in the network. Maximum number allowed is 1000 for large model, 500 for medium model and 100 for small model. If you add new pipes or delete pipes in the Pipe Data (Scr-El) screen then this total number of pipe changes automatically.

   Enter 15 as applicable for this example.

   Once you have entered the number of pipes, you cannot directly change the same by typing over. This could be done by pressing [F10] function key first (refer to the help menu) and then retyping immediately the new number of pipes. This extra precaution has been kept to protect accidental loss of data.

4. **Number of Nodes:** Type the total number of nodes in the network. Maximum number allowed is 750 for large model, 400 for medium model and 75 for small model. If you add new nodes or delete nodes in the Node Data (Scr-III) screen then this total number of nodes changes automatically.

   Enter 13 as applicable for this example.

   Once you have entered the number of nodes, you cannot directly change the same by typing over. This could be done by pressing [F10] function key first and retyping immediately the new number of nodes. As an example first move to the

next row by pressing <ENTER> and then by pressing <UP> arrow key, come under this field. Now try typing over 13 with say 10 without pressing [F10] key. Press <ENTER>*and you will find that the number 13 is unchanged.

5. **Type of Pipe Materials Used:** Type up to a maximum of 3 pipe materials abbreviated into two alphabets each and separated by a / (forward slash).

   A valid data entry for materials-such as Cast Iron, Mild Steel and HDPE may be,

   CI/MS/HD

   If you have only one material (say HDPE) but three pressure classes A, B and C, then the data entry might be,

   HA/HB/HC

   LOOP uses this information to set up the commercial pipe data entry screens.

   This specification is optional and in such case when this field is left blank "NA" appears against related fields in the later screens (only if the data file is saved and reloaded).

   Enter CI as applicable in this example.

5. **Number of Commercial Dia. per Material:** Enter the number of commercial diameters for each pipe material which are available for the design. If you are using 10 diameters of MUd Steel (MS) and 5 diameters of Cast Iron (CI), then you should type data as follows,

   10/5

   corresponding to MS/CI/ typed under the type of pipe materials used. The order should exactly follow the one followed in field 5.

   The total number of commercial diameters which can be considered is 30 for large and medium models and 20 for small model. Hence if you are specifying two pipe materials, then, by default, the maximum number of commercial diameters per material for large and medium model set up as 15 and for small model as 10.

   Enter 3 as applicable in this example.

7. **Peak Design factor**: Enter Peak Factor applied to the average dernand at all demand nodes. The peak factor is only applied to demand (i.e. negative flows) and not to flows contributing to the network (i.e. positive flows). Default is 1.

   Press <ENTER> to accept the default value.

8. **Type of Formula (1/2):** 1 denotes Hazen William's formula and 2 corresponds to Darcy-Weisbach expression. Default is Hazen William's formula i.e. 1.

Press <ENTER> to accept the default value.

The next seven data entry fields refer to the specification of units. User can make combination to minimize data conversion efforts. For all units, there are two options, designated as 1/2. To provide an instant explanation to what is implied by 1 or 2, LOOP displays a small text line on the same row for every specification of units.

9. **Unit of Pipe Length (1/2):** 1 denotes that data on pipe length is in meters while 2 implies that the same is in feet. Default is 1.

Enter 2 to indicate that the pipe length shall be entered in feet.

10. **Unit of Pipe Diameter (1/2):** 1 denotes that data on pipe diameters is in millimeters while 2 implies that the same is in inches. Default is 1.

Enter 2 to confirm that the pipe diameters shall be entered in inches.

11. **Unit of Pipe Flow (1/2):** 1 denotes that data on pipe flow is in liters/sec while 2 implies that the same is in cubic feet/sec. Default is 1.

Press <ENTER> key to confirm that the pipe flow shall be entered in liters/sec.

12. **Unit of Head (1/2):** 1 denotes that head is in meters while 2 implies that the same is in feet. Default is 1.

Enter 2 to confirm that the head shall be entered in feet.

13. **Unit of Elevation (1/2):** 1 denotes that data on node elevation is in meters while 2 implies that the same is in feet. Default is 1.

Enter 2 to confirm that the elevation shall be entered in feet.

14. **Unit of Pressure (1/2):** 1 denotes pressure in meters and 2 corresponds to pound per square inch (psi). Default is 1.

Enter 2 to confirm that the pressure shall be entered in psi.

15. **Unit of Velocity (1/2):** 1 denotes velocity in meter/sec and 2 corresponds to feet/sec. Default is 1.

Enter 2 to confirm that the velocity shall be entered in feet/sec.

After completing the details as appropriate to the TEST data file, press <TAB> to move to the Pipe Data (Scr-II) screen.

6.6 Pipe Data (Scr-II)

This screen is exclusively for entering the pipe details like pipe numbers, its starting or from node number, ending or to node number, and length of the pipe, etc.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing <ENTER> key. If you are having more than fourteen pipes, then the data is entered on the next page of the screen two. Press <PGUP> or <PGDN> to view the previous or next page respectively.

Explanation to the various data entry items to complete this screen is as below. See Appendix-B for the values to be entered for TEST network under each heading of this screen.

1. **Pipe No**.: It is the number of the pipes in the network. It is recommended that pipe numbers should be given in ascending order for better readability, but there is no such restriction. There is an option of *auto-numbering* for the pipes in the command line option and if opted for, LOOP displays the pipe numbers serially on pressing <ENTER> or <DOWN> key. The user can overwrite, if necessary.

2. **From Node**: It is the number of the starting or "From" node from which the pipe (as entered above) begins. The end at which a pipe starts is called "From Node". The two ends of a pipe are termed as "nodes" and each node is assigned a unique number. You can however have same node numbers as the pipe numbers.

3. **To Node** : It is the number of the end or "To" node where the pipe ends. The end at which a pipe ends is called "To Node".

4. **Length**: Enter the length of pipe, in relevant units.

5. **Diameter** : Enter the diameter of the pipe in appropriate units if the pipe is existing or if you wish to "force" your own option in the design. Leave the field blank if you want LOOP to find the diameter. If you are choosing Simulation (S) as the option in the Design Information (Scr-XIII) screen, (as applicable for this example), then for each pipe, a diameter must be entered.

6. **Hazen's/Darcy's Constant**: Enter the appropriate value for the corresponding pipe. Do not forget to distinguish between the old and the new pipe diameters. If no value is entered, then the value specified in appropriate commercial diameter screen is used as default.

7. **Pipe Mater** : Enter the material or pressure class of the pipe (in the two alphabet abbreviation made in the General Information (Scr-I) screen). This information must be entered if more than one pipe material is specified, otherwise the first pipe material will be assumed for the pipe.

8. **Exs/Parl** : This field is not really a 'data entry field but a "status field" to declare whether the pipe is existing *(E)* or a parallel pipe (P) is proposed. This can be done by using [F8] as follows,

[F8] Marks pipe as existing (E). Pressing [F8] again erases the existing status.

[Shift] + [F8] Marks pipe as parallel (P). Pressing [Shift] + [F8] again de-marks the parallel status.

Do not mark the field if pipe does not exist or no parallel pipe is to be proposed. If you are planning to choose Simulation (S) as the option in Design Information screen (Scr-XIII), do not mark any pipe as parallel. This is prompted as an error by the check data routine. In case you wish to include parallel pipes in the Simulation, you will have to create an extra pipe (i.e. two pipes having same "From" and "To" nodes as well as length but different pipe number).

If the pipe is marked as existing then its cost is not calculated. If the pipe is marked as parallel, then cost of the new parallel pipe is only calculated. It must be remembered that if the pipe is marked as parallel, its status is shown as existing in the output with another pipe (having same "From" and "To" nodes but a total new pipe number) added.

After completing the appropriate data entry, press the <TAB> key, to move to the Node Data (Scr-III) screen.

6.7 *Node Data (Scr-III)*

This screen is exclusively for providing the node related information such as water demand, peak factor, ground elevation, etc. Note that all node numbers (including source nodes), whether they contribute flow or not must be entered in this screen.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key. If you are having more than fourteen nodes, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively.

Explanation to the various data entry items to complete this screen is as below. See Appendix-B for the values to be entered for TEST network under each heading of this screen.

1. **Node No** : Type the node number for which the data is to be entered. The node numbers, as given, while entering "From" and "To" nodes in the previous screen (i.e. Scr-II) have to be used. The node numbers and other corresponding details can be entered in any order but it is preferable to enter them serially. Remember to enter the nodes including the source nodes. There is an option of *auto-numbering* for nodes similar to that of pipe numbers in the Pipe Data (Scr-II) entry screen,

Which displays the node numbers serially on pressing the <ENTER> or <DOWN> key. The user can however overwrite in case he does not prefer auto-numbering.

2. **Peak Factor** : This refers to the peaking factor applicable to the average flow. The peak factor is to be entered only to the demand nodes (i.e. negative flow nodes) and not to nodes contributing flows to the networks (i.e. positive flow nodes or source nodes). Default is the peak factor entered in the General Information (Scr-I) screen.

3. **Flow** : This refers to the average water demand at the corresponding node, in relevant units. The value must be preceded by a negative sign for demand. All flows arising from the nodes such as, .say a pump at a well which is known to deliver water at a certain rate regardless of the HGL, should be specified with a positive sign. These nodes may or may not be treated as source nodes. AH source nodes (those declared in Scr-IV) flows must be left blank.

4. **Elev**: Enter the ground level elevation at the corresponding node in relevant units.

5. **Min Pres** : This is the minimum pressure desired at the corresponding node. The default value for this node specific value is the minimum pressure specified in the Design Information (Scr-XIII) screen.

6. **Max Pres** : This is the maximum pressure desired at the corresponding node. The default value for this node specific value is the maximum pressure specified in the Design Information (Scr-XIII) screen.

After completing the appropriate data entry, press the <TAB> key, to move to the Number of Fixtures (Scr-IV) screen.

6.8 Number of Fixtures (Scr-IV)

This screen is exclusively for giving the details about the number of reservoirs, booster pumps, pressure reducing valves (PRV) and check valves(CV) which will be used in the design of the network. After entering the data, corresponding to each field as required, you can move to the next field by pressing the <ENTER> or <DOWN> key.

To enter the data in this screen follow the steps as given below:

1. **No. of Res. Nodes with Fixed HGL** : The number of source nodes haxong fixed HGL feeding the network.

   Example of a fixed HGL node is a large reservoir where the water elevation does not change significantly with demand.

   Enter 1 as applicable for this example.

2. No. of Res. Nodes with Variable HGL : The number of source nodes where HGL depends on the flow and hence is unknown. For all such nodes data on H-Q curves must be available.

   Example of a Variable HGL node is a pump feeding water from the source into the network.

   Enter 1 as applicable for this example.

3. **No. of Booster Pumps** : The number of on-line booster pumps.

   Leave this field blank since there are no booster pumps in this example.

4. **No. of Pressure Reducing Valves** : The number of Pressure Reducing Valves (PRV).

   Enter 3 as applicable for this example.

5. **No. of Check Valves** : The number of Check Valves (CV).

   Enter 1 as applicable for this example.

After completing the details as appropriate to the TEST data file, press <TAB> to move to the Fixed Head Reservoir Node Data (Scr-V) screen.

6.9 *Fixed Head Reservoir Node Data (Scr-V)*

This screen is exclusively for providing the details about reservoirs with fixed HGL. If in the Fixtures screen (Scr-IV), the number of fixed HGL reservoirs is declared as zero, then this data entry screen will not be shown.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key if. you are having more than fourteen reservoirs, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively.

Explanation to the various data entry items to complete this screen is as below. See **Appendix-B** for the values to be entered for TEST network under each heading of this screen.

1. **Node No**: It is the node number for the fixed HGL source or reservoir.

2. **1Head** : HGL of the corresponding source or reservoir node in relevant units.

3. **Ref Res** ? (R/N): Enter "R" to indicate that the corresponding source node is a reference node and "N" or blank if it is otherwise. From the number of fixed HGL or variable HGL sources, there could be only one reference node in the system. The

hydraulic grade line elevations for the whole network are calculated starting with that node. Refer to **Part III** for guidelines on how to choose a reference out of a number of reservoirs.

After completing the appropriate data entry, press the <TAB> key, to move to the Variable Head Reservoir Node data (Scr-VI) screen.

6.10 *Variable Head Reservoir Node Data (Scr-VI)*

This screen is for providing details about the sources with variable HGL (i.e. case of direct pumping of water in the distribution system). If in the Fixtures screen, the number of variable HGL reservoirs is declared as zero, then this data entry screen will not appear.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key. If you are having more than fourteen entries, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively. For each H-Q pair of data more than one H-Q pair, data on node number, number of pumps, number of points and reference reservoir need not be entered.

Explanation to the various data entry items to complete this screen is as below. Since there are no booster pumps declared for this example the values for TEST network under each heading does not appear in Appendix-B.

1. **Node No**. : Enter the node number for the variable HGL source or reservoir.

2. **No. of Pumps**: Enter the number of pumps at corresponding source node installed in parallel. If none entered, then one pump is assumed.

3. **No of Max Pts** : Enter the number of data points to be entered from the H(Head) Q(Discharge) curve. At least 4 H-Q points to be entered.

4. **X-Co-ord** : Enter the data point on the X-axis i.e. Discharge (Q) in relevant units.

5. **Y-Co ord** : Enter the data point on the Y-axis i.e. Head (H) corresponding to the data point on X-axis as entered, in relevant units.

6. **Pump Ele** : Elevation of the pump from the assumed datum for the whole network (and not just elevation of pump above the elevation of corresponding source-node) in relevant units.

7. **Ref Res ? (R/N)** : Enter "R" to indicate that the corresponding source node is a reference node and "N" for otherwise. From the number of fixed HGL or variable HGL reservoirs, there could be only one reference node in the system. The hydraulic grade line elevations for the whole network are calculated starting with that node.

Since we have not declared any of the fixed head reservoirs as reference for this example,type R to declare'this reservoir as a reference reservoir.

After completing press the <TAB> key, to move to the next data entry screen. Since in the Fixtures screen, we have declared the number of booster pumps as zero, the next . data entry screen will not be Scr-VII but Scr-VETI. However for the sake of completeness, we will describe Scr-VII as well.

6.11 *Description of Booster Pumps (Scr-VII)*

This screen seven is for providing the details about the booster pump location and details. If in the Fixtures screen, the number of booster pumps is declared as zero, then this data entry screen will not appear.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key. If you are having more than fourteen entries, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively. For each H-Q pair of data more than one H-Q pair, data on pipe number, number of pumps and number of points need not be entered.

Explanation to the various data entry items to complete this screen is as below. Since there are no booster pumps declared for this example the values for TEST network under each heading does not appear in Appendix-B.

1. **Pipe No.** : It is the number of the pipe where the booster pump is located. The direction of pumping is assumed in the direction of "From" to "To" nodes of that pipe as entered in Pipe Data (Scr-II) screen.

2. **Booster Pumps** : It is the number of booster pumps at corresponding pipe installed, in parallel. If none entered, then one pump is assumed.

3. **No of Max Pts** : This refers to the number of data points to be entered from the H(Head)-Q(Discharge) curve. At least 4 H-Q points are to be entered. However, recommended maximum H-Q points are 5.

4. **X-Co ord** : The data point on the X-axis i.e. Discharge (Q) in relevant units.

5. **Y-Co ord (H):** The data point on the Y-axis i.e. Head (H) corresponding to the data point on the X-axis as entered, in relevant units.

After completing the appropriate details, press the <TAB> key, to move to the PRY Description (Scr-VIII) screen.

6.12 *PRV Description (Scr-VIII)*

This screen is exclusively for giving the details about the PRV location and details. if in the Fixtures screen, the number of PRVs is declared as zero, then this data entry screen does not appear.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key. If you are having more than fourteen PRVs, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively.

Explanation to the various data entry items to complete this screen is as below. See Appendix-B for the values to be entered for TEST network under each heading of this screen.

1. **Pipe No** : Enter the pipe number where the PRV is located. Appropriate consideration for the orientation of pipe in the network system should be given i.e its "To" node must be on the downstream side of PRV. The direction of the PRV is assumed in the direction of "From" to "To" nodes of that pipe as entered in Pipe Data (Scr-n) screen.

2. **Source Node No**. : Enter the node number of the nearest or upstream source or reservoir node from this PRV. If none is entered then the reference reservoir node number is assumed.

3. **D/S Head** : Enter the operation head (that the PRV should maintain if operational), in relevant units for the downstream side.

4. **Resist Coeff** : Enter the resistance coefficient of the PRV (the head loss of PRV is assumed to be of form h=k*Q2). This must be developed in the appropriate units declared for flow and head.

Read Part III of the manual for familiarization with the various terminologies on PRVs.

After completing the appropriate details, press the <TAB> key, to move to the CV Description (Scr-IX) screen. Since in the Fixtures screen, we have declared the number of CV as zero, the next data entry screen will not be Scr-IX but Scr-X. However for the sake of completeness, we will describe Scr-IX as well.

6.13 CV *Description (Scr-IX)*

This screen is exclusively for providing the details about the Check Valve (CV) location.

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key. If you are having more than fourteen CVs, then the data is entered on the next page of the screen. Press <PGUP> or <PGDN> to view the previous or next page respectively.

Explanation to the various data entry items to complete this screen is as below.

1. **Pipe No**.: It is the pipe number containing the check valves. Appropriate consideration for the orientation of pipe in the network system should be given i.e. its "To" node must be on the downstream side of check valve. The direction of the CV is assumed in the direction of "From" to "To" nodes of that pipe as entered in Pipe Data (Scr-II) screen.

   Read Part III of the manual to be familiar with the various terminologies on CVs.

After completing press the <TAB> key, to move to the Commercial Diameter (Scr-X) screen.

6.13 *Commercial Diameter (Scr-X/XI/XII)*

These screens are exclusively for providing the details about the commercial pipe sizes for different pipe materials which are to be used for the design of the water distribution network. Since in this case CI has been the only pipe material declared in the General Information (Scr-I) screen, only one screen (viz. Scr-X) will be shown and the tile of the screen will be CI Commercial Diameter (Scr-X).

Data entered should be strictly in the units specified under the captions. After entering the data, corresponding to each column, you can move to the next column by pressing the <ENTER> key.

Explanation to the various data entry items to complete this screen is as below. See **Appendix-B** for the values to be entered for TEST network under each heading of this screen.

1. **Pipe Dia Int**: The internal diameter of the available set of commercial diameters for the particular class of pipe material, which is to be considered in the design of network, in relevant units.

2. **Hazen's/Darcy's Constant**:Enter the appropriate value for the corresponding pipe.

3. **Cost**: The unit cost of the corresponding diameter pipe in specified currency per unit length. This cost should include the cost of laying and jointing of pipe at the site.

4. **Allow Pre** : The maximum allowable working pressure for the corresponding pipe diameter and material in relevant units.

Depending on the number- of pipe materials, number of Commercial Diameter screens will be shown (i.e. if only one pipe material is used then the Scr-XI and Scr-XII will not be shown), on pressing the <TAB> key. Since we have declared only one pipe material for this example, the next data entry screen will not be Scr-XI and Scr-XII but Scr-XIII.

6.15 Design Information (Scr-XIII)

This screen is kept for the declaration of the water distribution network design policies. The design process of LOOP can be controlled significantly by choosing the various options from this screen. After entering the data, corresponding to each field as required, you can move to the next field by pressing the <ENTER> or <DOWN> key.

To enter the data in this screen follow the steps as given below,

1. **Newton-Raphson Stopping Criterion**: This criterion refers to the maximum allowable error in flow in any pipe while balancing heads. If this value is too large then the balancing of heads and flows may not be proper. On the other hand, if the value is too small, then the balancing may take quite a long time. The default is 0.001.

   Press <ENTER> key to accept the default value as applicable for this example.

2. **Minimum Pressure**: Enter the desirable minimum pressure at the nodes to be maintained in the distribution network. Normally for urban areas the minimum pressure to be specified varies between 7 meters to *17* meters. Default value here is 17 meters.

   Enter 40 (psi) as applicable for this example.

3. **Maximum Pressure**: Enter the desirable maximum pressure to be maintained in the distribution network. Normally for urban areas the maximum pressure to be allowed is between 40 to 80 meters. Default is 40 meters.

   Enter 90 (psi) as applicable for this example.

4. **Design Hydraulic Gradient**:The design hydraulic gradient significantly influences the initial design or pipe sizing of the network. Normally, some practical range is used by designers as a guideline to design or master plan the looped water distribution system. It is recommended that 5/1000 for smaller networks and 2/1000 for larger networks corresponding to peak flows are taken. Default value is (2/1000).

   Press <ENTER> key to accept the default value as applicable for this example.

5. **Simulate or Design**? **(S/D):** Indicate whether to "S"imulate or "D"esign the distribution network. Option "S" is the default.

Press <ENTER> key to accept the .default value i.e. simulation of network as applicable for this example.

After completion of this screen if the <TAB> key is pressed, then the General Information (Scr-I) screen will be shown again or else press <ESC> to return to File . Menu.

Thus after completing the data file TEST.LOP, exit the data entry editor using <ESC>. Then save the TEST file by selecting the *Save Data File* option of File Menu.

Press <ESC> and return to the Main Menu. Select print option and print the data file on the printer. Check all the data entered with the print out of the TEST data file attached in Appendix-B. Since you have created a new file, you can opt to check the data using option of *Check Data* from the File Menu to ensure that no syntactical errors have been made.

6.16 Check Data File

Whenever you create a new file, choose the option of *Check Data* from the File Menu for syntactical errors. Check data option performs extensive set of tests on the data file. Some of the checks include,

- whether there is a mismatch between minimum and maximum value (eg. you cannot declare value of minimum pressure greater than the value ot maximum pressure)

- whether there is any mismatch between node numbers and "From" and "To" node declaration done for pipes

- whether the "From" or "To" node numbers or pipe numbers are repeated (e.g. you cannot have two pipes having same numbers)

- whether the network connectivity is maintained (i.e. it is not fragmented)

- whether the diameters declared in all the pipe screens belong to commercially declared diameters

- whether there is a duplication in the commercial diameters

- whether the source node is declared as the source node in node screen, (e.g. source should have zero or positive flow as declared in Node Data (Scr-III). .

- whether the pipe number which appears in on-line booster pump screen, pressure reducing valves screen and check valves screen appears in pipe data screen.

If the program points out any error, go back to data entry and correct the mistake. Since the method of error trapping is step by step (i.e. not all at one time), repeat the *Check Data* option till no error is pointed out.

Whether you ask for check .data in File Menu or not, the same is run automatically during the design process. Thus, LOOP ensures that the input data file passed on to the design routine is syntax error free and reasonable to the extent possible.

To understand, the role of check data, make some changes in your data file to learn how check data prompts you for the data entry or syntax error.

6.17 Solve TEST Network

Having checked the data file, press <ESC> to return to Main Menu and choose the *Solve Network* option.

You will see a sequence of messages just like while solving DEMO file but this time you will have an opportunity to see typical valve operation messages sent to the screen. Please refer to the description on PRVs and CVs in **Part III** of this manual to understand the technical implications of valve setting and operation.

Save the output file from the Display Menu and print the output using the *Print Files* option of the Main Menu. Check whether the results obtained match with the output of TEST data file given in **Appendix - B.**

This tutorial with TEST.LOP must have given you confidence to try out your own design strategies or introduce changes in the data file. There could be several possibilities worth exploring. Following additional runs will show the flexibility of LOOP. These are,

1. Add a check valve in pipe number 11. Addition of a check valve will alter the flow directions and quantities in the pipes. The results should show a general increase in the node pressures and the input flow distribution of the two sources almost equal as,

	Source Node 2 ps	**Source Node 11 lps**
Before Check valve Addition	**45.51**	**69.97**
After Check Valve Added	**55.52**	**59.96**

PRV/CV status will show an additional message,

Pipe #11 containing a CV is Operating

2. Strengthen the TEST network for a minimum pressure constraint of 75 psi at node 6 with a demand of 1.5 times the existing demand.

To achieve this requirement, place a booster pump in pipe 102 with following H-Q characteristics,

X-Co ord	Y Co- ord
Ips-	ft
84.95	116.71
42.475	329.18
28.317	368.50
0.0	400.00

To reflect the action of strengthening, do not forget to turn the status of all the pipes to "Existing" so as to ignore the pipe cost calculations.

The results will show that a booster pump based on the theoretical requirements of 92.01.Ips and a head of 67.60 ft may be ordered to meet this objective. A summary of results will be,

	Source Node 2 Ips	Source Node 11 Ips	Pressure Node 6 psi
Before Booster Pump	45.51	69.97	54.36
After Booster Pump	56.22	60.84	76.06

6.18 Computation Time Required

The design and simulation processes may take a couple of minutes if the network is large (number of pipes and nodes) or if you are using a relatively slow computer. The computation time increases with the presence of fixtures such as valves. Newton-Raphson stopping criterion also influences the number of iterations and hence the computation time.

Following is a comparative statistics for TEST data file as applicable to different PCs.

Type of PC			Time Required for Design in Seconds
PC	..	4.77 Mhz	180
PC/XT	"	10 Mhz_	100
PC / AT		12 Mhz	10
with Maths Co-processor			
PC / AT		16 Mhz	7
with Maths Co-processor -			

* After check data and with /iN option in the command line and a Design hydraulic gradient of 10.

PART-III

7.0 Technical Description

Computer based analysis and design of looped water distribution systems is becoming increasingly popular in the recent times. Computer models are now accepted as a reliable source of information for making engineering and operational decisions.

Given the network topology, supply and demands nodes and pipe characteristics, the computer models can simulate flows in pipes, and pressures at nodes in looped water distribution systems. The models may be used to,

1. Simulate alternative pipe size and layouts to determine which combination of pipes can deliver adequate flow and pressure.

2. Simulate flows and pressures with alternative locations and capacities of pumps and reservoirs to identify most effective combinations.

3. Conduct sensitivity analysis for future growth of demands and identify which of the existing pipes need strengthening, cleaning or lining.

The subject of water distribution networks can be broadly divided into Simulation and Design. Simulation refers to solving for flows and pressures in the network for the given set of pipe sizes (pipes may either exist or may be assigned commercial diameters). Design refers to finding pipe sizes (wherever pipe sizes are unknown) such that the flows and pressures in the network are reasonably acceptable and yet the solution is economical. It could be observed that simulation is a special case of design while design includes simulation.

7.1 Simulation

A water distribution system model represents a set of nodes connected by pipes. Nodes (or junctions) can be a point along a pipe where pressure heads are to be calculated. Nodes can thus be placed anywhere along a pipe, but because too many nodes tend to slow down the computation process and increase the memory requirements, nodes are usually only assigned to intersections of pipes, changes in pipe diameters, major water demands, dead end segments and reservoirs/sources. Nodes are connected by pipes and pipes can contain fixtures such as check valves, pressure reducing valves or booster pumps.

The central part of the computer model like LOOP, consists of the numerical method used for solving the steady state flow equations. There are two types of equations that are encountered in the looped water distribution systems:

1. Continuity - at each node the flow 'in' must be equal to the flow 'out'.

2. Energy - the nett head loss around each loop must be zero, and the head loss between two reservoirs must be equal 'to the difference in the water level between the reservoirs.

In the most general formulation, there is one continuity equation for each node (balancing flows), one energy equation for each pipe (balancing heads), and one pump/reservoir equation for each operating pump/reservoir. The system of equations resulting on combination are solved using some numerical technique.

For the distribution systems encountered in practice, the number of loops is smaller than the number of nodes (smaller by 25% [4]). Thus the computation work for balancing heads is less than that for balancing flows. LOOP uses the method of balancing heads using Newton-Raphson technique.

For the estimation of hydraulic gradient (S) through a pipe flowing full, LOOP allows Hazen-William's and Darcy-Weisbach's expressions which in MKS units are given as,

Hazen-William's expression,

$$V = 0.85 * C * R^{0.63} * S^{0.54} \qquad \text{... (1)}$$

where, R is the hydraulic radius given by (D/4) where
D is the pipe diameter in m.
S is the hydraulic gradient in m/m
C is the Hazen-William's constant which depends on the pipe material.

Darcy-Weisbach expression,

$$V = S^{0.5} x (2 g x D)^{0.5} x f^{0.5} \qquad \text{... (2)}$$

Where, f = Darcy's friction factor given by,

$$1/f^{0.5} = -2 x \log (k/(3.7 D) + 2.51/(R_e x f^{0.5})) \qquad \text{... (3)}$$

Where, k = roughness height in meters
Re = Reynolds's number

Equation (3) was originally proposed by Colebrook-White and is an implicit in nature requiring iterative procedure to compute f. LOOP makes use of an explicit and accurate form of this equation as developed by Jain [5] as,

$$1/f^{0.5} = 1.14 - 2 x \log (k/D + 21.25/ R_e^{0.9}) \qquad \text{... (4)}$$

7.1.1 Newton *Raphson Method [2]*

Consider a function of x i.e. F(x) as shown in Figure 11 and let 'a' be one of its roots so that F(a) = 0. To find 'a' by trial and error procedure, assume that x is taken as X for the first trial. Naturally $F(x_i)$ is not equal to zero. Let (6(x)) be the correction so that F(x + (5 x)) = 0. Expanding by Taylor's theorem,

$$F(x_i) + F'(x_i) * \delta(x) + F''(x_i) * \delta(x)^2 / 2! + ... = 0 \qquad ... (5)$$

in which F’ and F”denote the first and the second derivatives of F(x) respectively with the value of Xj substituted for x. If δ (x) is small compared to x (as it will be when x approaches a, the third and the subsequent terms of the expansion can be neglected giving,

$$\delta (x) = - F (x>) / F' (x_j) \qquad ...(6)$$

This argument can be extended to a set of simultaneous equations involving more than one variable. Thus for two variables x and y,

$$\text{Let } F_1, (x) = 0 \qquad ..(7)$$

$$\text{and } F_2 (x) = 0 \qquad ..(8)$$

be the two equations for the two variables x and y. If x, and y, are the two trial'values and if (x) and (y) are the corrections, then as before,

$$F, (x, + \delta (x), y_: + \delta (y)) = 0 \text{ and} \qquad ...(9)$$

$$F_2 (xj + \delta (x), {}_{yi} + \delta (y)) = 0 \qquad ...(10)$$

Expanding and neglecting higher order terms,

$$F_1(x_1, y_1,) + [\delta(F_1) / \delta (x_1) * \delta (x) +[\delta(F_1) / \delta(y_1)] * \delta (y)=0 \qquad ...(11)$$

$$F_1(x_1, y_1,) + [\delta(F_2) / \delta (x1) * \delta (x) +[\delta(F2) / \delta(y1)] * \delta (y)=0 \qquad ... (12)$$

Writing in the matrix form,

$$\begin{vmatrix} \delta(F_1) / \delta\,(x_1) & \delta(F_1) / \delta\,(x_1) \\ \delta(F_2) / \delta\,(x_1) & \delta(F_2) / \delta\,(y_1) \end{vmatrix} \begin{vmatrix} \delta\,(x) \\ \delta\,(y) \end{vmatrix} = - \begin{vmatrix} F_1 \\ F_2 \end{vmatrix} \qquad \ldots(13)$$

Applying this formulation for the case of balancing heads, if F_1, F_2 F_3 ... F_1 are the loop headless equation values, then

$$\begin{vmatrix} \delta(F_1) / \delta\,(Q_1) & \delta(F_1) / \delta\,(Q_1) \\ \delta(F_2) / \delta\,(Q_1) & \delta(F_2) / \delta\,(Q_1) \\ \ldots & \ldots \\ \delta(F_1) / \delta\,(Q_1) & \delta(F_1) / \delta\,(Q_1) \end{vmatrix} \begin{vmatrix} Z_1 \\ Z_2 \\ \ldots \\ Z_1 \end{vmatrix} = \begin{vmatrix} F_1 \\ F_2 \\ \ldots \\ F_1 \end{vmatrix}$$

where, Z_1, Z_2, ... Z_L are the corrections to the assumed values of $\delta\,(Q_1)$, $\delta\,(Q_2)\ldots\delta\,(Q_1)$ respectively.

It could be easily observed that the first matrix on the left hand side (called as the Jacobian matrix) is symmetric in nature. The above simultaneous equations could be solved using techniques such as Cholesky Decomposition. This technique has been employed in LOOP. The equations could be repeatedly solved using updated values of Z till the Max(Zi) is negligibly small. LOOP refers to this value as Newton-Raphson Stopping Criterion.

This method of balancing heads was first introduced by Martin and Peters [8] and has been successfully used by Pitchai [9], Shamir and Howard [10], Epp and Fowler [4], Lam and Wolla [7] etc. As the Newton-Raphson method considers all the loops simultaneously, the convergence as far as the number of iterations are concerned is fast as compared to Hardy-Cross method, however the computational work required per iteration is relatively more. Additionally, the memory requirements are also higher.

7.1.2 Initialization of Flows

LOOP uses a strategy to automatically identify the loops using the concept of-minimum path [4]. Having defined the loops, it sets the initial flows in pipes by identifying the minimal spanning tree such that all demands are correctly balanced by the source nodes. For pipes not included in the minimum spanning tree, zero initial flows are assigned. The advantages of using this strategy as reported in [4] are,

1. In a spanning tree, by definition, any two nodes are connected by one and only one path.

2. Using the minimal spanning tree with the length of each pipe equal to the resistance of the pipe, pipes with the smallest resistance tend to get assigned zero initial flows. This gives quite a reasonable approximation to the true flow which in turn reduces the number of iterations required to find the final flow and even more important, in practice, seems to assure convergence of the Newton's method.

7.1.3 Minimization of the Bandwidth

An effective means of substantially improving the computational efficiency of obtaining solution to the above equations, is to band the Jacobian matrix. Epp and Fowler [4] describe a method of banding the Jacobian by numbering the loops such that the non zero elements in the equations are brought towards the diagonal, a procedure which is called as minimization of the Band width. LOOP provides information on the band width during the solution process if an option of /iY is used in the command line. Band width depends on the network configuration, number of sources and in the case of multiple sources, which source node is declared as the reference node.

The size of the Jacobian is computed as Bandwidth times the Number of loops. This is in fact the real memory restriction on LOOP and not the pipe or node numbers!. LOOP uses a dynamic memory management strategy to allocate maximum space available to the storage of Jacobian during run time. If adequate storage is not available, then a message "Matrix Overflow" is displayed, aborting the calculation process. In case of such a message, check the RAM, network data and whether reference source is properly assigned. If the data is correct and error cannot be resolved, then the only way out is to divide the network into two independent networks and solve separately.

7.1.4 ***Source Nodes***

Source nodes are nodes where water enters the network, and there must be at least one of them. There could be two types of source nodes -one where the HGL is fixed (or known) and other where HGL is variable (but with a known function of flow, such as for pumps). For a variable HGL source node, it is not possible to fix both flow and the HGL at that node, since the system is then "over-determined", and mathematically there is no solution. If there is only one source (fixed or variable) node, then the HGL throughout the network is calculated starting at that node.

If there are two or more source nodes, the calculations are more complex. Since the HGL is known (or at least a function of flow) at each of the source nodes, the system must be balanced in such a way as to maintain the implied HGL differences between the various source nodes. This is done by varying the amount of flow such that each source node contributes so as to produce the necessary HGL differences.

The LOOP program does this by finding *a* suitable set of pipes (preferably of large diameters) between one of the source nodes and all the others. This "line" is called as "pseudo-loop". If an energy balance is not possible to achieve in such a pseudo loop, then LOOP sends a message "Energy Balance Violated - Trying to Resolve Conflict". The program attempts resolving the conflict up to three times by "adjusting" the Jacobian, but if the same cannot be resolved then sends a message to check the source data and abort the calculation process. The probable error in such situations is normally in the H-Q data points of variable head reservoirs or due to. very high HGL specified for closely spaced fixed head reservoirs or due to specification of large diameter pipes between closely spaced reservoirs.

If there are only two source nodes, then there is only one pseudo line, and therefore, which source node is chosen as the reference node is not of concern. However, if there are three or more source nodes, then the reference node should be the one that is most "central" to the network, relative to the location of all of the source nodes. For example, there are three source nodes, and two of them are close together, whereas the third one is on the other side of the network, choose one of the two nodes that are dose together as the reference node. This strategy greatly helps in the minimization of the bandwidth and hence reduction in the RAM requirements.

For Variable Head Source Nodes, the formula for calculating the HGL is,

$$H = [\, P_0 + P_1Q + P_2Q^2 + P_3Q^3 \,] + P_4 \quad \text{... (15)}$$

In the case of Variable Head Source Nodes, LOOP determines the constants, P_Q, P_1, P_2 and P_3 using least squares regression based on H-Q data taken from the pump characteristics. There are three important points to be considered while specifying Variable Head Source Data.

1. Be sure that the H-Q data strictly follows the units declared during entry of data.

2. Coefficient P_4 is not really computed and must be provided by the user since it represents the elevation of the pump from datum so that the total HGL could be computed. In the case of fixed head reservoir, P_0 represents the total HGL and hence the user is not asked to enter data on P_4 separately.

For Booster pumps, the formula for calculating the HGL is,

$$H = [\, B_0 + B_1Q + B_2Q^2 + B_3Q^3 \,] \quad \text{... (16)}$$

In case of booster pumps, these are fixed on-line (or on the pipe), fourth parameter, B_4 can be estimated using the data on node elevations. The instructions for inputting H-Q data for Variable Head Sources is also applicable for the booster pumps.

7.1.5 *Pressure Reducing Valves and Check Valves*

A pressure reducing valve (PRV) is designed to maintain a constant downstream pressure regardless of the upstream pressure. The exceptions to this occurrence are,

1. If the upstream pressure becomes less than the valve setting, the valve becomes inoperative and the analysis proceeds as if no PRV was present.

2. If the downstream pressure exceeds the pressure setting of the valve, the PRV acts as a check valve preventing reverse flow. By preventing reverse flow, the PRV functions as a check valve and allows pressure immediately downstream from the valve to exceed its pressure setting. Thus, the PRV is used to reduce pressures in portions of the pipe distribution system if the pressures are otherwise be excessive or it may be used to control from which source of supply, or pipes, the flow comes under various demand levels. The PRV acts as check valve until the upstream pressure is reduced to critical levels by large demands, at which time additional sources of water are drawn upon.

A PRV can be operational and non-operational. When non-operational, it is assumed that the valve is wide open. Here, the PRV does have additional resistance over and above that provided by the pipe itself. Most manufacturers report that this additional head loss (due to resistance of the open valve) can be approximated by an equation of the form $h= K * Q^2$ where h is the head loss and Q is the flow through the PRV. LOOP requires the value of K (not to be confused with the pipe resistance coefficients k or C) which the user should supply consulting the catalogue of the manufacturer. However, once the PRV becomes operating, K is not relevant and so it may be generally set to zero as default.

Check Valves (CV) allow the flow of pipe in only one direction. If the check valve is placed on the pipe, its direction is considered as the direction implied by From and To nodes of the pipe. If the actual direction of flow is reverse of the assumed direction, the CV is not operational. If a check valve is "operating", that is no water is flowing through the pipe, LOOP removes the whole pipe from the system and repeats the whole calculation. While "removing" the pipe, network gets fragmented, an appropriate message is shown.

In LOOP, it is assumed that the resistance factor K for flow through a CV can either be zero (valve wide open)_or infinite (valve fully closed). If you want to simulate a partially open valve or a valve with certain resistance factor, then declare this valve as a PRV. Specify it in PRV data entry screen (Scr-VIII), and provide appropriate resistance factor K and a very high requirement of downstream head. The PRV under this condition will not be operating but the flow through PRV will suffer a loss of head depending on resistance factor K and pipe velocity V.

The analysis of pipe networks containing PRVs and CVs must determine whether the valves are in normal mode of operations (i.e. operating) or with any other conditions, _ and then apply appropriate techniques to obtain valid solution. In order to confirm that valves are "operating", the network has to be solved, or almost solved. This is achieved' by not allowing the check to be made on check valves and PRVs until the flows are almost settled. LOOP sets a criteria for "Testing PRV/CV" when maximum (Q) falls within five times of the Newton-Raphson stopping criterion.

When pressure reducing valves (PRV) are present, the above procedure of using

same loops for energy equations and corrective flow rates must be altered. Reasons why the same loops cannot be used are,

1. The head drop across PRV cannot be expressed as a function of the (Q) circulating through that pipe (in fact the head drop across PRV is independent of flow rate)

2. Continuity at some junctions is no longer satisfied if the δ (Q) is assumed to circulate through the pseudo loops starting at artificial reservoirs created by PRV to another reservoir (or source pump) of the network.

For networks containing PRV, the individual values of δ (Q) are assumed to circulate around the basic loops of the network, which are defined identically in same manner as if no PRV existed. The energy equations are then written around loops that are defined by disconnecting the pipes containing PRV from their upstream junctions and by replacing PRV with artificial reservoirs.

Consider the seven pipe network shown in Figure 12 in which PRV is placed in pipe 2 (Refer to Jepson [6] for more details). The corrective flow rates 4Qi) and 4(Q2) are assumed to circulate around two basic loops containing pipes 1, 2, 3, and 4; and 6, 7, and 2, respectively. The energy equations are written around the loops defined by dashed lines in Figure 12. One of the loops is encompassing both basic loops and other is a pseudo loop that proceeds from the artificial reservoir replacing the PRV, in the most direct route to the supply reservoir. The energy equations are,

$$Fl = K_1 (Q_{01} + \Delta Q_1)^{a1} + K_6 (Q_{06} + \Delta Q_2)^{a6} +$$

$$K_7 (Q_{07} + \Delta Q_2)^{a7} - K_3 (Q_{03} - \Delta Q_1)^{a3} -$$

$$K_4 (Q_{04} + \Delta Q_1)^{a4} = 0 \qquad \text{...(17)}$$

$$F2 = K_2 \ (Q_{02} + \Delta Q_{1\,-}\ \Delta Q_2)^{n2} \ - \ K_3 (Q_{03} - \Delta Q_1)^{n3} \ -$$

$$K_5 = \ (Q_{05})^{n5} + H_1 - (HGL)_1 = 0 \qquad \text{...(18)}$$

In order to simulate the PRVs correctly, LOOP finds a path between the node upstream from the PRV to some source node. The path may go through other PRVs, but if so, it is ensured that the same goes through the PRV in one direction only, namely, from the downstream side of the PRV to the upstream side. However, in certain network configurations, it is not possible to find such a pathway. User is asked to provide the node number of the source node which in most cases could simply be the reference node itself.

7.2 *Handling Pipes with Different Materials/Pressure Classes*

LOOP allows the user to specify up to three types of pipe materials while describing the pipe network. The user can specify pipe materials (in the abbreviation of two alphabets) such as Cast Iron (CI), Mild Steel (MS) or Asbestos Cement (AC) etc. If HOPE pipes of different pressure classes are to be used then, user may declare pipe

materials as H1, H2 and H3 indicating pipes of three different classes. It is necessary that the user inputs pipe materials for each pipe in the system; however if none is specified then *LOOP* assumes that the first pipe material has been used.

LOOP uses the information on pipe material in determining the pipe sizes.

7.3 Parallel Pipes

LOOP allows the user to indicate pipes where a parallel pipe may be proposed. LOOP adds an extra pipe to the total number of pipes internally and proceeds with simulation and design. The material of the parallel pipe is taken as that of the existing or primary pipe.

7.4 ***Network Geometry Constraints***

Some of the important restrictions for the use of LOOP related to network geometry are as follows,

1. Number of parallel pipes cannot exceed 40% of the total number of pipes declared or total number of pipes declared plus the number of parallel pipes cannot exceed the maximum allowable number of pipes. In such a case, an error message appears as

Too Many Parallel Pipes in Network
Change Memory Model or Simplify Network

For example, if you run LOOP with 300 pipes and medium model, then you cannot define more than 40% of 300 pipes viz. 120 parallel pipes. Further, if you are having 400 pipes with medium model, then you cannot define more than 25% of 400 pipes viz. 100 pipes as parallel pipes since the sum total (400 plus 40% of 400 pipes) exceeds the maximum allowable 500 pipes.

3. In LOOP, each node in a network can be at most connected to 4 pipes. In practice, we rarely have networks where each node is connected to more than 4 pipes. Generally the average connectivity for a node will be around 2 or 3. For instance, as an extreme, some nodes may have only one pipe connected while there can be some nodes with more than 6 pipes connected; averaging out the connectivity equal to or less than 4.

If the average connectivity of the network increases beyond 4, then an error message is flashed as,

Too Many Pipes Connected to Node/s, Simplify Network

In such instances, the system may be decomposed by introducing additional zero demand nodes with short lengths to reduce the connectivity.

7.5 Design

Design of a looped water distribution network involves selection of an appropriate pipe diameter for every pipe, so that the water can be transported without violating specified hydraulic constraints and the desired minimum pressures maintained at nodes. Options for the location and capacity of source nodes are normally relatively few and are hence prefixed. The usual process is one of trial and error, where the engineer attempts a set of pipe sizes and checks the hydraulic conditions to see if they are adequate. If not the engineer changes the pipe sizes heuristically (or changes the pump locations and capacities if possible) to arrive at a workable alternative. Cost estimates, on which a final decision has to be based are made for each feasible alternative for the purpose of ranking.

It seems at first that the computer programs could directly solve the network for the required pipe sizes. However, this cannot be done however for real problems because for any problem of significant size, there are many combinations of pipes that are possible. Therefore, evaluation of a very large number of options to arrive at the best solution is needed. The problem is further compounded because pipes are available only in discrete sizes and cost-headloss relationships are nonlinear. Theoretically, as stated by Templeman [11], the optimization problem does not have a truly global least cost solution. The best we can expect therefore is identification of a good sub-optimal solutions.

Numerous researchers have proposed methods for determining optimal pipe sizes in real world water distribution systems (refer to Walski [12] for a comprehensive review). Although all the methods can provide some useful insight for selecting pipe diameters, they may not give practical and at the same time good sub-optimal solutions. It is not surprising therefore, that there are indeed very few pipe sizing (or design) computer models developed.

Apart from the total costs, there are many facets of pipe sizing that can only be addressed qualitatively by an engineer using judgment, insight and experience. As Walski et al [14], in the paper on *"Battle of Network Models - Epilogue"* states, *"...while the pipe network optimization programs can assist the engineer in selecting pipe sizes, a great deal of engineering judgment and experience is needed to determine the low cost workable solution. ... Locations of source nodes and capacities are portions of the problem which can be cited as examples of users intervention ".*

7.5.1 ***Pipe Sizing Algorithm used by LOOP***

The algorithm used for finding sizes of pipes in *LOOP* is only a tool to provide a good starting solution for the user to further improve on the solution. The procedure -followed is heuristic and is derived from the work reported by Dixit and Rao [3]. This., method has been found to be working quite well when compared to other theoretically rigorous methods. (Refer to Dixit [2] for a detailed comparison) and is hence expected to result in a quick and good starting solutions. The algorithm followed in LOOP is an extension of this approach by introducing certain generalities. Reasons for relying on such an approach are as follows,

1. The extended approach is easy to understand and to explain to the design engineer.

2. The algorithm is quite efficient in terms of solution rime as well as memory resources as compared to techniques such as Linear Programming (LP) or Non-linear Programming (NLP); the latter consideration being quite critical in terms of implementation of the code of LOOP on Personal Computer (PC) environment.

3. The algorithm considers diameters in the discrete commercial form (unlike non-linear programming) and does not presupposes a flow distribution (unlike in linear programming).

4. The computational performance of the algorithm excels the other optimization techniques in terms of its robustness and speed. The optimal solutions obtained by this algorithm compare favorably (in some instances are found even better) with those obtained by other optimization techniques.

The premise of the algorithm is as follows,

The main constraint in the sizing of pipes is that the pressures at the nodes should satisfy the specified minimum, say $h_m i_n$. If the head at a source is H^ then pipe sizes should be selected such that,

$$H, - \text{(head loss due to friction)} >= h_{min} \quad ... (19)$$

If headloss due to friction is represented by Darcy-Weisbach expression, then (in MKS units).

$$(H, - h_{min}) / L >= f Q^2 / [(2 g D) * (3.14 * D^2/4)^2] \quad ... (20)$$

or for economical solution,

$$(H, - h_{min}) / L = f Q^2 / (12.1 * D^5) \quad ... (21)$$

where,

L is the length of the flow path between the source and node where pressure, at least equal to h_{min}, is to be maintained. Equation (21) could be directly used for sizing diameter D of length L spanning between one source and a demand node.

For a looped system consisting of several pipes and sources, equation (21) cannot -be used as a one step procedure since it is difficult to identify both critical node and its,.. path length with respect to multiple sources. There could be some situations however where a good estimate of path length can be obtained by studying the pipe layout.

It could be noted that the term [(H, - h_{min})/L] represents the maximum allowable hydraulic grade line in the system. Normally, it is the experience that some practical range is used by designers as a guideline to design or master plan the looped water

distribution system. Walski et. al. [13] recommend that a guideline of 5/1000 and 2/1000 for smaller and larger networks -respectively. It is pragmatic that the designer uses a prefixed or preferential value as maximum allowable grade line (MaxHyGrd) rather than attempting the exact calculation of [(Hs - h_{min})/L]. The philosophy of using a guideline .'estimate is more towards relying on actual experience of the designers on the behavior of the networks. Equation (21) could be then expressed as,

$$MaxHyGrd = f\,Q^2 / (12.1 * D^s{}_1) \qquad ...\ (22)$$

hence rearranging,

$$Qi = (MaxHyGrd * 12.1 * D^s{}_1 / f)^{os} \qquad ...\ (23)$$

It could be interpreted that for a network with known pipe sizes D,, and specified or targeted MaxHyGrd, the flows through the pipes should be as close to Q, so as to lead to a cost-effective solution. In such a case, Q_1 in various pipes may be considered as near *optimal* flows.

For networks with unknown pipe sizes then, a following iterative algorithm could be used,

1. Prepare a table of diameters (Dj) and corresponding optimal discharges (Q,) for all the commercial diameters which are used in the design.

2. Assume maximum available commercial diameters in all new or "diameter free" pipes (where diameters have not been forced) and analyze the system for pressures at nodes. If the solution is not feasible, terminate the computational process. User has to change the inputs on source nodes and/or pressure constraints. If the solution is feasible, then compute the cost of all new pipes in the network and proceed.

3. For every new pipe, compare the actual flow in the pipe with the corresponding optimal flow developed in step 1. The criteria for updating the diameter D, is as follows,

   Firstly, out of the set of commercial diameters, *two* diameters, say $D_($ and $D_{(i+1)/}$ are found such that,

$$Q_1 < abs(Q) < Q_{i+1} \qquad ..(24)$$

where abs(Q) denotes the absolute value of flow through the pipe.

The next task then is to find the new size of the pipe i.e. whether D_i or $D_{(i+1)}$. For this purpose, following proximity rule is used,

$$\text{If } Q_1 < abs(Q) < (Q_i + Q_{(i+1)}) /2 \text{ then } D = D_1 \qquad ...\ (25)$$

And

$$\text{If } Q_{i+1} > abs(Q) > (Q_i + Q_{(i+1)}) /2 \text{ then } D = D_{i+1} \qquad ...\ (26)$$

If abs(Q) is so low that abs(Q) < Q, (suffix 1 denotes the smallest given commercial diameter), then D is set equal to Dj. Similarly, it' abs(Q) is higher than Q_{NComm} (suffix NComm denotes the largest given commercial diameter), then D is set to D_{Ncomm}).

4. Update all new pipe diameters as per step 3 and re-analyze the system for pressures. If the solution is feasible, then the cost of all the new pipes in the system is computed and compared with the previous feasible cost. If the cost is reduced, move to step *3*.

   If the cost remains unchanged for two successive computational cycles, then terminate the algorithm, assuming that all flows are now falling in the corridors of optimal discharge.

   If an infeasible solution is struck while updating the pipe sizes, make it feasible by incrementing pipe by one size for all new pipes, which connect to the nodes having low pressure.

   The final solution of the algorithm is a feasible solution. Normally, if a proper value of MaxHyGrd is set then not more than five to six (generally three) iterations of diameter updates are required to reach a cost-effective solution.

It could be observed that the pipe sizing process followed in this algorithm is of successive approximation and can be effectively controlled by the user using a design value of MaxHyGrd. If a higher value of MaxHyGrd is used, then pipe sizes found are relatively smaller, with possibilities of infeasible solution being struck in the second or third diameter update. If a lower value of MaxHyGrd is used, then the pipe sizes tend to be larger and the final solution though feasible may correspond to more expensive solution. User can thus generate different starting solutions using this algorithm for subsequent "touches" or "improvements".

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LOOP Version 4.0 Input.Data File :DEMO.LOP Page # 1

Title of the Project : Loop Design Sample
Name of the User : Sumito

- Number of Pipes : 24
Number of Nodes : 20

Type of Pipe Materials Used : CI/
Number of Commercial Dia per Material : 6/

Peak Design Factor : 2
Newton-Raphson Stopping Criterion Ips : .001
Minimum Pressure m : 7
Maximum Pressure m : 30
Design Hydraulic Gradient m in km : 5
Simulate or Design? (S/D) : S

No. of Res. Nodes with Fixed HGL : 1
No. of Res. Nodes with Variable HGL : 0
No. of Booster Pumps : 0
No. of Pressure Reducing Valves : 0
No. of Check Valves : 0
Type of Formula : Hazen's

Pipe No.	From node	To node	Length m	Diameter mm	Hazen'sConst	Pipe Material	Status(E/P)
1	300	1	800.00	200.0	110.00000	Cl	
2	1	3	350.00	100.0	110.00000	Cl	
3	1	2	500.00	150.0	110.00000	Cl	
4	2	7	600.00	75.0	110.00000	Cl	
5	3	4	720.00	75.0	110.00000	Cl	
6	1	5	700.00	100.0	110.00000	Cl	
7	2	6	750.00	50.0	110.00000	Cl	
8	7	8	700.00	50.0	110.00000	Cl	
9	5	4	350.00	100.0	110.00000	Cl	
10	6	5	500.00	100.0	110.00000	Cl	
11	6	8	600.00	150.0	110.00000	Cl	
12	4	11	800.00	75.0	110.00000	Cl	
13	11	13	900.00	150.0	110.00000	Cl	
14	12	13	550.00	50.0	110.00000	Cl	
15	8	12	800.00	100.0	110.00000	Cl	
16	8	9	500.00	150.0	110.00000	Cl	
17	9	10	650.00	100.0	110.00000	Cl	
18	9	17	800.00	75.0	110.00000	Cl	

Pipe no.	From node	To node	Length m	Diameter mm	Hazen's Const	Pipe Material	Status (E/P)
19	12	17	500.00	75.0	110.00000	Cl	
20	13	14	350.00	150.0	110.00000	Cl	
21	14	15	900.00	100.0	110.00000	Cl	
22	14	16	1200.00	100.0	110.00000	Cl	
50	100	11	500.00	150.0	110.00000	Cl	
60	200	6	350.00	200.0	110.00000	Cl	

Node Data

Node No.	Peak	Flow 1ps	Elevation m	Min Press m	Max Press M
1	2.00	-2.600	15.00	7.00	30.00
2	2.00	-3.400	15.00	7.00	30.00
3	2.00	-1.500	15.00	7.00	30.00
4	2.00	-1.300	15.00	7.00	30.00
5	2.00	-1.200	15.00	7.00	30.00
6	2.00	-1.500	15.00	7.00	30.00
7	2.00	-1.200	15.00	7.00	30.00
8	2.00	-1.300	15.00	7.00	30.00
9	2.00	-1.200	10.00	7.00	30.00
10	2.00	-2.600	10.00	7.00	30.00
11	2.00	-1.300	10.00	7.00	30.00
12	2.00	-1.400	10.00	7.00	30.00
13	2.00	-1.500	10.00	7.00	30.00
14	2.00	-1.800	10.00	7.00	30.00
15	2.00	-1.600	10.00	7.00	30.00
16	2.00	-2.100	10.00	7.00	30.00
17	2.00	-1.300	10.00	7.00	30.00
300	2.00	0.000	10.00	7.00	30.00
100	2.00	15.000	10.00	7.00	30.00
200	2.00	20.000	10.00	7.00	30.00

Source Node	Head m	Ref Res? (R)
300	40.00	R

Commercial Diameter Data

Pipe Dia Int. (mm)	Hazen's Const	Unit Cost Rs / m length	Allow Press m	Pipe Material
50.0	110.00000	10.00	100.00	**Cl**
75.0	110.00000	20.00	100.00	**Cl**
100.0	110.00000	30.00	100.00	**Cl**
150.0	110.00000	40.00	100.00	**Cl**
200.0	110.00000	50.00	100.00	**Cl**
250.0	110.00000	60.00	100.00	**Cl**

Echoing input Design Variables

. Title of the Project : Loop Design Sample
Name of the User : Sumito
Number of Pipes : 24
Number of Nodes : 20
Type of Pipe Materials Used : CI/
Number of Commercial Dia per Material : 6/
Peak Design Factor : 2
Newton-Raphson Stopping Criterion 1ps : .001
Minimum Pressure m : 7
Maximum Pressure m : 30
Design Hydraulic Gradient m in km : 5
Simulate or Design? (S/D) : S
No. of Res. Nodes with Fixed HGL : 1
No. of Res. Nodes with Variable HGL : 0
No. of Booster Pumps " : 0
No. of Pressure Reducing Valves : 0
No. of Check Valves : 0
Type of Formula : Hazen's

Looped Water Distribution Network Design Output

BandWidth = 3
Number of Loops = 5
Newton Raphson Iterations = 6

Pipe Details

Pipe no.	From node	To node	Flow (1ps)	Dia (mm)	HL (m)	HL/ 100m (m)	Length (m)	Velocity (m / s)
1	300	1	22.600	200.0	3.22	4.02	800.00	0.75
2	1	3	4.245	100.0	1.86	5.32	350.00	0.54
3	1	2	9.621	150.0	1.68	3.36	500.00	0.54
4	2	7	2.586	75.0	5.17	8.62	600.00	0.59
5	3	4	1.245	75.0	1.60	2.23	720.00	0.28
6	1	5	3.534	100.0	2.65	3.79	700.00	0.45
7	2	6	0.234	50.0	0.55	0.73	750.00	0.12
8	7	8	0.186	50.0	0.33	0.48	700.00	0.09
9	5	4	2.715	100.0	0.81	2.32	350.00	0.35
10	6	5	1.580	100.0	0.33	0.85	500.00	0.20

Pipe Details cont'd

Pipe no.	From node	To node	Flow (1ps)	Dia (mm)	HL (m)	HL/ 100m (m)	Length (m)	Velocity (m / s)
11	6	8	15.64	150.0	4.96	8.27	600.00	0.89
12	4	11	1.360	75.0	2.10	2.62	800.00	0.31
13	11	13	13.760	150.0	5.86	6.51	900.00	0.78
14	12	13	0.240	50.0	0.42	0.76	550.00	0.12
15	8	12	4.004	100.0	3.82	4.77	800.00	0.51
16	8	9	9.236	150.0	1.56	3.11	500.00	0.52
17	9	10	5.200	100.0	5.03	7.74	650.00	0.66
18	9	17	1.636	75.0	2.95	3.69	800.00	0.37
19	12	17	0.964	75.0	0.69	1.39	500.00	0.22
20	13	14	11.000	150.0	1.51	4.30	350.00	0.62
21	14	15	3.200	100.0	2.84	3.15	900.00	0.41
22	14	16	4.200	100.0	6.26	5.21	1200.00	0.53
50	100	11	15.000	150.0	3.82	7.64	500.00	0.85
60	200	6	20.000	200.0	1.12	3.21	350.00	0.64

Pipe Pressure Details

Pipe No.	From Node	To Node	Dia (mm)	Hazen's Const	Pipe Material	Max Press (m)	Allow Press (m)	Status (E / P)
1	300	1	200.0	110.00000	Cl	30.00	100.00	
2	1	3	100.0	110.00000	Cl	21.78	100.00	
3	1	2	150.0	110.00000	Cl	21.78	100.00	
4	2	7	75.0	110.00000	Cl	20.10	100.00	
5	3	4	75.0	110.00000	Cl	19.92	100.00	
6	1	5	100.0	110.00000	Cl	21.78	100.00	
7	2	6	50.0	110.00000	Cl	20.10	100.00	
8	7	8	50.0	110.00000	Cl	14.93	100.00	
9	5	4	100.0	110.00000	Cl	19.13	100.00	
10	6	5	100.0	110.00000	Cl	19.56	100.00	
11	6	8	150.0	110.00000	Cl	19.56	100.00	
12	4	11	75.0	110.00000	Cl	21.22	100.00	
13	11	13	150.0	110.00000	Cl	21.22	100.00	
14	12	13	50.0	110.00000	Cl	15.78	100.00	
15	8	12	100.0	110.00000	Cl	15.78	100.00	
16	8	9	150.0	110.00000	Cl	18.04	100.00	
17	9	10	100.0	110.00000	Cl	18.04	100.00	
18	9	17	75.0	110.00000	Cl	18.04	100.00	
19	12	17	75.0	110.00000	Cl	15.78	100.00	
20	13	14	150.0	110.00000	Cl	15.36	100.00	
21	14	15	100.0	110.00000	Cl	13.85	100.00	

Pipe Pressure Details cont'd

Pipe No.	From Node	To Node	Dia (mm)	Hazen’s Const	Pipe Material	Max Press (m)	Allow Press (m)	Status (E / P)
22	14	16	100.0	110.00000	Cl	13.85	100.0	
50	100	11	150.0	110.00000	Cl	25.04	100.0	
60	200	6	200.0	110.00000	Cl	25.68	100.0	

Node Details

Node No.	Flow (1ps)	Elev. (m)	H G L (m)	Pressure (m)
1	-5.200	15.00	36.78	21.78
2	-6.800	15.00	35.10	20.10
3	-3.000	15.00	34.92	19.92
4	-2.600	15.00	33.32	18.32
5	-2.400	15.00	34.13	19.13
6	-3.000	15.00	34.56	19.56
7	-2.400	15.00	29.93	14.93
8	-2.600	15.00	29.60	14.60
9	-2.400	10.00	28.04	18.04
10	-5.200	10.00	23.01	13.01
11	-2.600	10.00	31.22	21.22
12	-2.800	10.00	25.78	15.78
13	-3.000	10.00	25.36	15.36
14	-3.600	10.00	23.85	13.85
15	-3.200	10.00	21.02	11.04
16	-4.200	10.00	17.60	7.60
17	-2.600	10.00	25.09	15.09
300S	22.600	10.00	40.00	350.0.00
100	15.000	10.00	35.04	25.04
200	20.000	10.00	35.68	25.68

Pipe cost Summary

Diameter (mm)	Pipe Material	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
50.0	CI	2000.00	20.00	20.00
75.0	CI	3420.00	68.40	88.40

Pipe Cost Summary cont'd

Diameter (mm)	Pipe Material	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
100.0	Cl	5450.00	163.50	251.90
150.0	Cl	3350.00	134.00	385.90
200.0	Cl	1150.00	57.50	443.40

Pipe-Wise Cost Summary

PipeNo	Diameter (mm)	Pipe Material	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
1	200.0	Cl	800.00	40.00	40.00
2	100.0	Cl	350.00	10.50	50.50
3	150.0	Cl	500.00	20.00	70.50
4	75.0	Cl	600.00	12.00	82.50
5	75.0	Cl	720.00	14.40	96.90
6	100.0	Cl	700.00	21.00	117.90
7	50.0	Cl	750.00	7.50	125.40
8	50.0	Cl	700.00	7.00	132.40
9	100.0	Cl	350.00	10.50	142.90
10	100.0	Cl	500.00	15.00	157.90
11	150.0	Cl	600.00	24.00	181.90
12	75.0	Cl	800.00	16.00	197.90
13	150.0	Cl	900.00	36.00	233.90
14	50.0	Cl	550.00	5.50	239.40
15	100.0	Cl	800.00	24.00	263.40
16	150.0	Cl	500.00	20.00	283.40
17	100.0	Cl	650.00	19.50	302.90
18	75.0	Cl	800.00	16.00	318.90
19	75.0	Cl	500.00	10.00	328.90
20	150.0	Cl	350.00	14.00	342.90
21	100.0	Cl	900.00	27.00	369.90
22	100.0	Cl	1200.00	36.00	405.90
50	150.0	Cl	500.00	20.00	425.90
60	200.0	Cl	350.00	17.50	443.40

LOOP
Version 4.0

Program for Design of
Looped Water Distribution Network

Title of the Project .		: Example 1 from Wadiso
Name of the User		: Sumito
Number of Pipes		:15
Number of Nodes		:13
Type of Pipe Materials Used		:CI/
Number of Commercial Dia per Material		:3/
Peak Design Factor		:1
Newton-Raphson Stopping Criterion	Ips	:001
Minimum Pressure	psi	:40
Maximum Pressure	psi	:90
Design Hydraulic Gradient ft in 1000ft		:2
Simulate or Design?	(S/D)	:S
No. of Res. Nodes with Fixed HGL		:1
No. of Res. Nodes with Variable HGL		:1
No. of Booster Pumps		:0
No. of Pressure Reducing Valves		:3
No. of Check Valves		:0
Type of Formula		: Hazen's

Pipe Data

Pipe No.	From Node	To Node	Length ft	Diameter in	Hazen's Const	Pipe Material	Status (E/P)
11	3	13	1800.00	8.0	100.00000	CI	
13	6	16	1000.00	10.0	100.00000	CI	
31	13	33	1000.00	8.0	100.00000	CI	
22	15	25	10.00	8.0	100.00000	CI	
32	25	35	1000.00	8.0	100.00000	CI	
23	16	26	10.00	8.0	100.00000	CI	
33	26	36	1000.00	8.0	100.00000	CI	
101	2	3	2000.00	12.0	100.00000	CI	
102	3	6	1500.00	10.0	100.00000	CI	
111	11	13	5000.00	12.0	100.00000	CI	
112	13	15	1500.00	8.0	100.00000	CI	
114	15	16	1500.00	8.0	100.00000	CI	
122	33	34	10.00	8.0	100.00000	CI	
123	34	35	1500.00	8.0	100.00000	CI	
124	35	36	1500.00	8.0	100.00000	CI	

Node No.	Peak	Flow 1ps	Elevation ft	Min Press psi	Max Press Psi
2	1.00	0.000	950.00	40.00	90.00
3	1.00	0.000	910.00	40.00	90.00
6	1.00	-3.160	905.00	40.00	90.00
11	1.00	0.000	950.00	40.00	90.00
13	1.00	0.000	920.00	40.00	90.00
15	1.00	-5.050	890.00	40.00	90.00
16	1.00	-4.730	890.00	40.00	90.00
25	1.00	0.000	890.00	40.00	90.00
26	1.00	0.000	890.00	40.00	90.00
34	1.00	0.000	870.00	40.00	90.00
33	1.00	-3.160	870.00	40.00	90.00
35	1.00	-4.730	870.00	40.00	90.00
36	1.00	-94.650	850.00	40.00	90.00

Fixed Head Reservoir Data

Source Node	Head ft	Ref Res ? (R)
2	1050.00	R

Variable Head Reservoir Data

Source Node	Nos. Pumps	Nos. Pts	X-Coord 1ps	Y-Coord ft	Pump Elev. Ft.	Ref Res ? (R)
11	1	4	84.950	113.84	950.00	
			56.630	133.85		
			28.320	146.30		
			0.000	151.20		

Pressure Reducing Value Data

PRV Pipe No.	Source Node	Oper. Head Ft	Resist Coeff.
22	11	1027.00	0.00000
23	11	1027.00	0.00000

Pressure Reducing Valve Data

PRV Pipe No	Source Node	Oper. Head ft	Resist Coeff.
122	11	1007.00	0.00000

Commercial Diameter Data

Pipe Dia. Int. (in)	Hazen's Const	Unit Cost Rs /ft length	Allow Press psi	Pipe Material
8.0	100.00000	19.30	0.00	CI
10.0	100.00000	28.90	0.00	CI
12.0	100.00000		0.00	CI

Echoing Input Design Variables

. Title of the Project		: Example 1 from Wadiso
Name of the User		: Sumito
Number of Pipes		: 15
Number of Nodes		: 13
Type of Pipe Materials Used		: CI/
Number of Commercial Dia per Material		: 3/
Peak Design Factor		: 1
Newton-Raphson Stopping Criterion	Ips	: .001
Minimum Pressure	psi	: 40
Maximum Pressure	psi	: 90
Design Hydraulic Gradient ft in 1000ft		: 2
Simulate or Design?	(S/D)	: S
No. of Res. Nodes with Fixed HGL		: 1
No. of Res. Nodes with Variable HGL		: 1
No. of Booster Pumps		: 0
No. of Pressure Reducing Valves		: 3
No. of Check Valves		: 0
Type of Formula		: Hazen's

Looped Water Distribution Network Design OutPut

BandWidth = 2
Nuinber of Loops = 3
NeVvton Raphson Iterations = 6

Pipe Details

Pipe No.	From Node	To Node	Flow (Ips)	Dia (in)	HL (ft)	HL/lOOOft (ft)	Length (ft)	Velocity (ft/s)
11	3	13	-17.309	8.0	-4.88	-2.71	1800.00	-1.75
13	6	16	59.659	10.0	9.04	9.04	1000.00	3.86
31	13	33	3.160	8.0	0.12	0.12	1000.00	0.32
22	15	25	39.605	8.0	0.13	12.55	10.00	4.01
32	25	35	39.605	8.0	12.55	12.55	1000.00	4.01
23	16	26	59.775	8.0	0.27	26.89	10.00	6.05
33	26	36	59.775	8.0	26.89	26.89	1000.00	6.05
101	2	J»	45.510	12.0	4.51	2.25	2000.00	2.05
102	3	6	62.819	10.0	14.92	9.95	1500.00	4.07
111	11	13	69.970	12.0	24.98	5.00	5000.00	3.15

Pipe Details cont'd

Pipe No.	From Node	To Node	Flow dps)	Dia (in)	HL (ft)	HL/lOOOft (ft)	Length (ft)	Velocity (ft/s)
112	13	15	49.501	8.0	28.45	18.97	1500.00	5.01
114	15	16	4.846	8.0	0.38	0.26	1500.00	0.49
122	Pipe Flow Zero due to Valve Action						10.00	
123	34	35	0.000	8.0	0.00	0.00	1500.00	0.00
124	35	36	34.875	8.0	14.87	9.92	1500.00	3.53

Pipe Pressure Details

Pipe No.	From Node	To Node	Dia (in)	Hazen's Const	Pipe Material	Max Press (psi)	Allow Press (psi)	Status (E/P)
11	3	13	8.0	100.00000	CI	58.74 HI	0.00	
13	6	16	10.0	100.00000	CI	57.02 HI	0.00	
31	13	33	. 8.0	100.00000	CI	78.14 HI	0.00	
22	15	25	8.0	100.00000	CI	57.19 HI	0.00	
32	25	35	8.0	100.00000	CI	60.37 HI	0.00	
23	16	26	8.0	100.00000	CI	57.02 HI	0.00	
33	26	36	8.0	100.00000	CI	62.59 HI	0.00	
101	2	3	12.0	100.00000	CI	58.74 HI	0.00	
102	3	6	10.0	100.00000	CI	58.74 HI	0.00	
111	11	13	12.0	100.00000	CI	56.52 HI	0.00	
112	13	15	8.0	100.00000	CI	57.19 HI	0.00	
114	15	16	8.0	100.00000	CI	57.19 HI	0.00	
122	Pipe	Flow	due	Valve Action				
123	34	35	8.0	100.00000	CI	60.37 HI	0.00	
124	35	36	8.0	100.00000	CI	62.59 HI	0.00	

Node No.	Flow dps)	Elev. (ft)	H G L (ft)	Pressure (psi)
2 S	45.510	950.00	1050.00	43.35
3	0.000	910.00	1045.49	58.74
6	-3.160	905.00	1030.58	54.44
11 S	69.970	950.00	1075.36	54.34
13	0.000	920.00	1050.37	56.52

Node No.	Flow Ops)	Elev. (ft)	H G L (ft)	Pressure (psi)
15	-5.050	890.00	1021.92	57.19
16	-4.730	890.00	1021.54	57.02
25	0.000	890.00	1021.79	57.14
26	0.000	890.00	1021.27	56.91
34	0.000	870.00	1009.25	6037
33	-3.160	870.00	1050.25	78.14
35	-4.730	870.00	1009.25	60.37
36	-94.650	850.00	994.37	62.59

Pipe Cost Summary

Diameter (in)	Pipe Material	Length (ft)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
8.0	CI	10830.00	209.02	209.02
10.0	CI	2500.00	72.25	281.27
12.0	CI	7000.00	283.50	564.77

Pipe No	Diameter (in)	Pipe Material	Length (ft)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
11	8.0	CI	1800.00	34.74	34.74
13	10.0	CI	1000.00	28.90	63.64
31	8.0	CI	1000.00	1930	82.94
22	8.0	CI	10.00	0.19	83.13
32	8.0	CI	1000.00	1930	102.43
23	8.0	CI	10.00	0.19	102.63
33	8.0	CI	1000.00	1930	121.93
101	12.0	CI	2000.00	81.00	20193
102	10.0	CI	1500.00	4335	246.28
111	12.0	CI	5000.00	202.50	448.78
112	8.0	CI	1500.00	28.95	477.73
114	8.0	CI	1500.00	28.95	506.68
122	8.0	CI	10.00	0.19	506.87
123	8.0	CI	1500.00	28.95	535.82

Piperwise Cost Summary cont'd

Pipe No	Diameter (in)	Pipe Material	Length (ft)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
124	8.0	CI	1500.00	28.95	564.77

Variable Head Reservoir Statistics

Node No.	PO	PI	P2	P3	No Pump	Pump Ht (ft)	Flow/Pump (lps)	Head (ft)
11	151.20	-.396E-01	-.471E-02	-.284E-08	1	950.00	69.97	125.36

PRV/CV Status

1 PRV in Pipe # 22 is Not Operational
2 PRV in Pipe # 23 is Not Operational
3 PRV in Pipe # 122 is Acting as CV